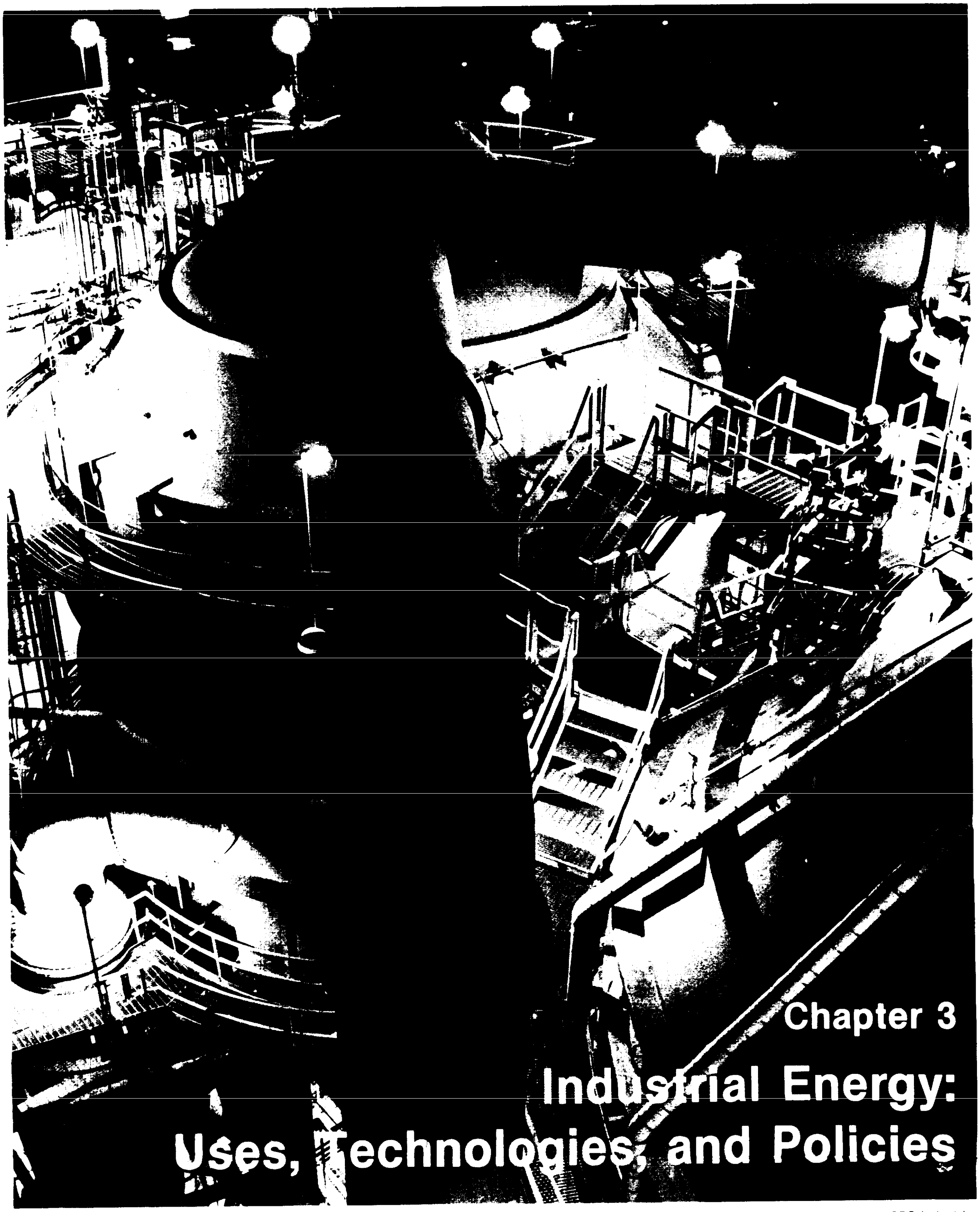

# Chapter 3

# Industrial Energy: Uses, Technologies, and Policies

*Photo credit: PPG Industries*

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# Chapter 3
# Industrial Energy: Uses, Technologies, and Policies

## INDUSTRIAL ENERGY

Energy does not flow through the industrial sector in simple or direct ways. Some energy or energy-bearing materials are recycled and reused. Substantial portions of energy used are derived from unusual sources. Some materials are processed in ways that yield both energy and feedstock value. Finally, some energy materials are not used at all for energy purposes. Thus, conceptual and data collection problems arise in defining and measuring the energy used by the industrial sector. [1]

### Sources of Industrial Energy

In the industrial sector, petroleum is the dominant energy source for motor-driven mechanical equipment of agriculture and construction. Natural gas is the dominant energy source in mining because of its availability in the relatively remote operations of the oil and gas extraction industry. Natural gas is used in manufacturing because it burns cleanly and provides easy flame control. It has also been used as a feedstock and as fuel for the special needs of a number of processes, such as glass manufacture and some ceramic production processes.

The use of petroleum and coal as raw materials accounts for about half of the manufacturing use of each of these fuels. [2] Most of the remaining half of petroleum use in manufacturing is for direct heat or for steam generation. This is also true for coal, but coal is used more for steam generation because there are relatively few goods produced using direct heat that can tolerate the impurities emitted by burning coal. For some energy uses, particularly for large boilers (for water heating or steam production), coal, oil, and gas are easily interchangeable in a technical, if not economical, sense. Many facilities, in fact, have dual or even triple fuel capabilities—with oil and natural gas the most likely combination.

As with other energy use variables, the diversity of use of various energy sources is more striking at lower levels of aggregation. Table 6, which shows energy use by source for the divisions, also has data for three selected industries in the manufacturing and mining divisions. Papermills, with a wide distribution of purchased energy source use, contrast with steel, which is heavily dependent on coal and coke, and the chemicals industry, which uses large quantities of natural gas and electricity. overall industrial energy use from 1950 to 1980 is shown in figure 7.

### Energy Costs

Although the use of energy in industry is a major contributor to the character of modern economies, the share of energy in the total cost of producing goods is relatively small. In manufacturing, for example, purchased energy (fuels and electricity) accounted for only 7.5 percent of gross product in 1979, even after the steep energy price increases of the 1970's. Given the variability of energy intensiveness across industries, the relative share of energy in total production costs is much higher in the more energy-intensive industries. Thus, the cost of purchased energy equaled 23 percent of the cement industry's value of shipments in 1979, 14 percent of the paperboard industry's value of shipments, and 25 to 30 percent of those for steel mills.

The degree of the energy price increases of the 1970's should not be understated. prior to the early 1 970's, manufacturers' energy costs rose moderately in nominal terms and actually fell relative to inflation. Between 1970 and 1979, however, the average real cost of fuels and electricity purchased by manufacturers increased from

[1] Substantial parts of the discussion concerning the definition, measurement, and determinants of industrial energy use are based on material in the following: John G. Myers, et al., *Energy Consumption m Manufacturing* (Cambridge, Mass.: Ballinger Publishing Co., 1974); John G. Myers and Leonard Nakamura, *Saving Energy* in Manufacturing: The Post-Embargo *Period* (Cambridge, Mass.: Ballinger Publishing Co., 1978), and Bernard A. Gelb and Jeffrey Pliskin, *Energy Use in Mining: Patterns and Prospects* (Cambridge, Mass.: Ballinger Publishing Co., 1979).

[2] Metallurgical coal that is converted to coke is counted as a raw material.



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**Table 6.—U.S. Industrial Energy Use by Source (quadrillion Btu)**

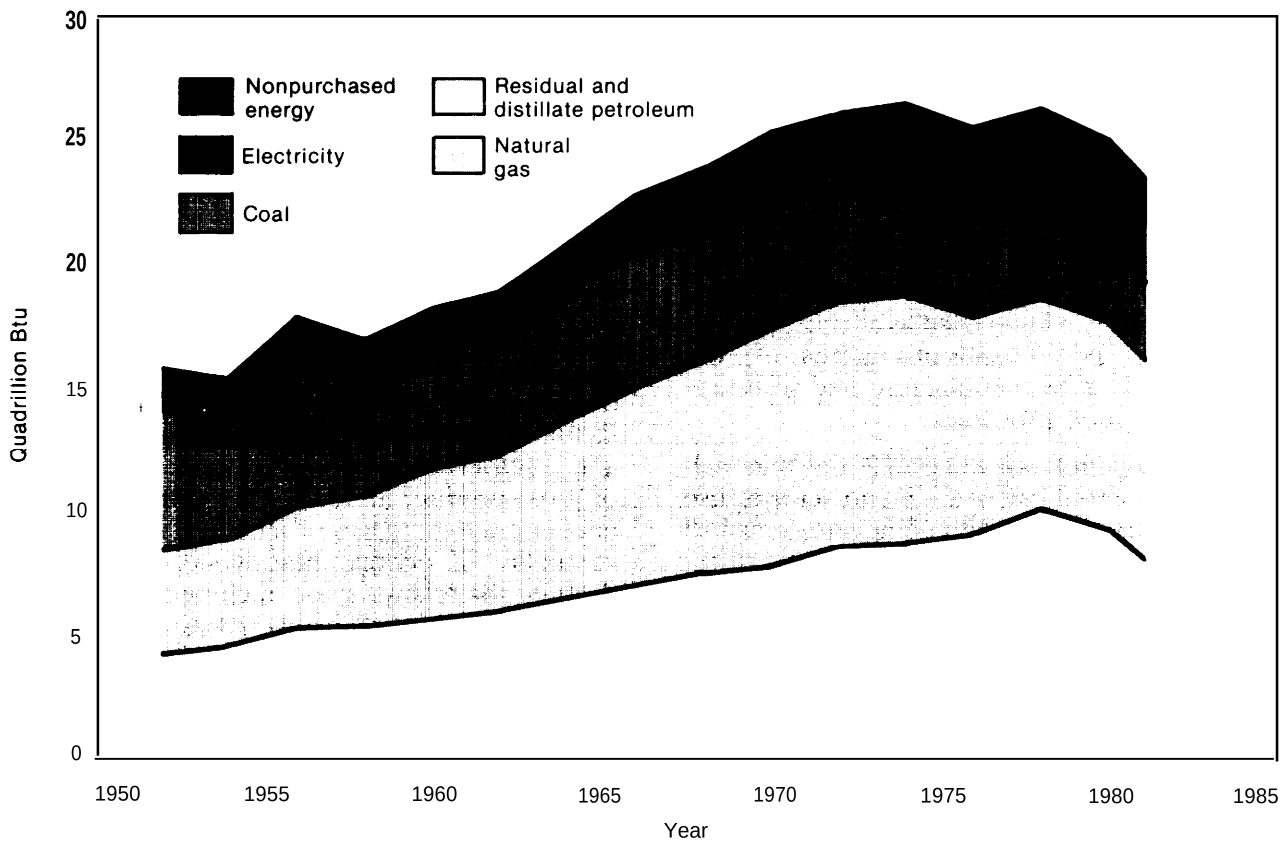
| Energy source | Entire industrial sector, 1981 | Sector divisions, 1979[a] | | | | Selected industries, 1979[b] | | |
|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Construction | Manufacturing | Papermills | Steel industry | Chemicals industry |
| Coal and coke | 3.12 | (c) | 0.10 | (c) | 3.69 | 0.18 | 1.91 | 0.31 |
| Natural gas | 8.12 | 0.17 | 1.70 | (c) | 6.67 | 0.41 | 0.64 | 1.37 |
| Petroleum | 8.12 | 1.32 | 0.62 | 1.58 | 6.68 | 0.41 | 0.21 | 0.76 |
| Purchased electricity at 3,412 Btu/kWh | 2.85 | 0.13 | 0.26 | 0.02 | 2.50 | 0.15 | 0.17 | 1.00 |
| Total | 22.21 | 1.62 | 2.68 | 1.60 | 19.54 | 1.15 | 2.93 | 3.44 |

NOTE: Recent revisions of petroleum and natural gas use data by DOE have been substantial, and make it difficult to reconcile DOE figures on energy use by fuel with figures published by the Bureau of the Census for manufacturing and mining.

[a]Estimated.
[b]purchased energy only.
[c]None, or less than 5 trillion Btu.

SOURCE: Energy Information Administration, U.S. Department of Energy, *Month/y Energy Review,* March 1982; *End Use Energy consumption Data Base: Series 1, Tables,* June 1978; Economics, Statistics, and Cooperative Service, U.S. Department of Agriculture, *Energy and U.S. Agriculture: 1974 and 1978,* April 1980; Bureau of the Census, U.S. Department of Commerce, *1979 Annual Survey of Manufactures and 1977 census of Mineral Industries;* American Iron and Steel Institute, *Annual Statistical Report* for 1960; Chemical Manufacturing Association, "1980 Report to the Office of Industrial Programs, Department of Energy."

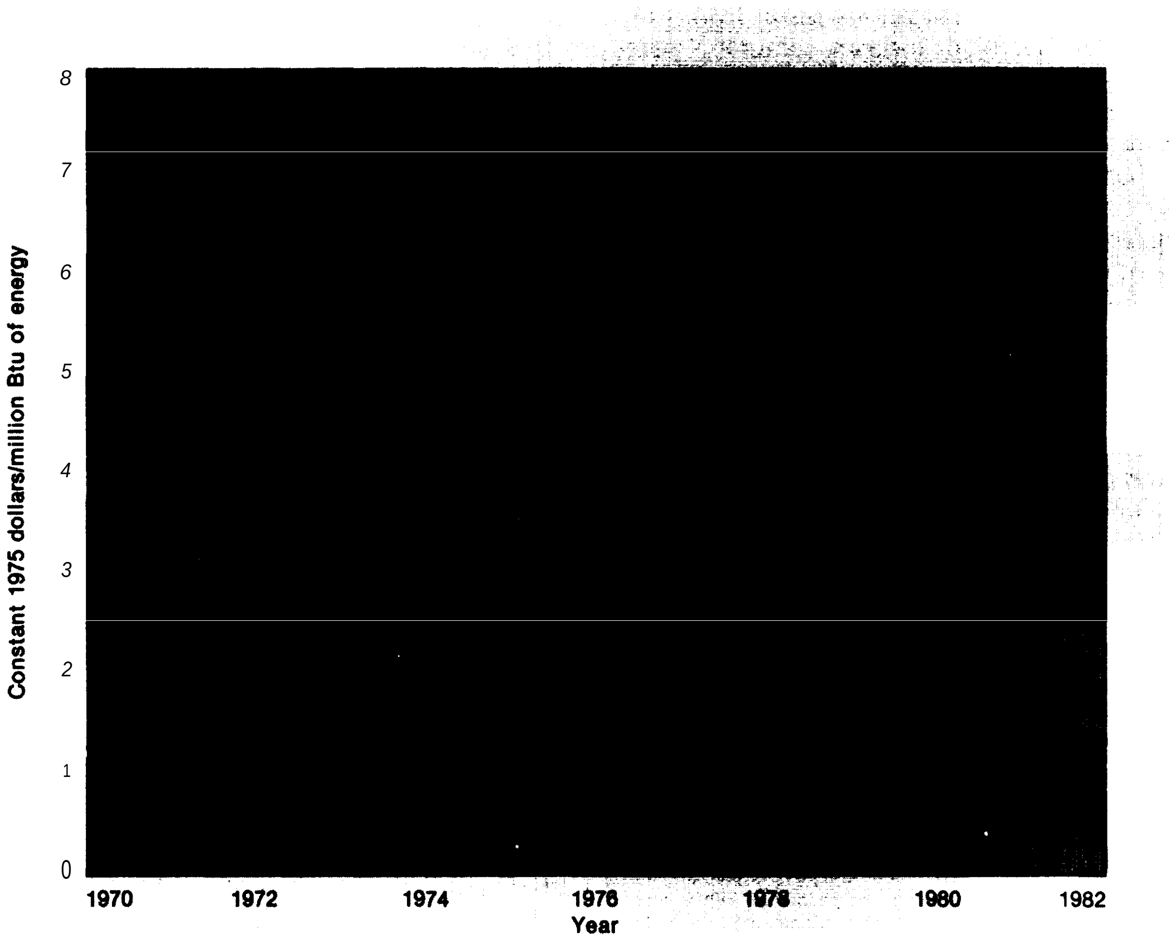
**Figure 7.—industrial Energy Use, 1950-81**




SOURCE. Energy Information Administration

$2.34 to $4.44 per million Btu (see fig. 8). The cost per million Btu of distillate oil jumped from $1.76 to $5.31, and that for natural gas increased from $0.63 to $1.76. Despite this dramatic increase in energy prices, the mix of energy sources used by manufacturers continued its pre-1971 trend toward more expensive energy sources (oil and electricity) and away from coal, at least until 1979.

**Figure 8.—Industrial Energy Prices, 1970-81**




SOURCE: Energy Information Administration.

# CHARACTERISTICS OF INDUSTRIAL ENERGY USE

The manner of accounting for energy use in this report is defined as the attribution to industry (or its divisions) of the energy that is applied or converted to nonenergy products. This is the so-called disappearance approach. As a consequence of the way in which energy use and related data are collected, what is actually measured and reported is the quantity of fuels and electricity purchased by the industrial sector that does not leave the sector as fuel or electricity. This approach has the disadvantage of excluding from energy use the process byproducts and waste materials that are consumed for their heat value.* It also excludes utility generation and transmission losses.

If defined to exclude utility generation and transmission losses, industrial energy use directly reflects changes in technology, product mix, and other developments in a sector or industry. On the other hand, distortions result from this method if the sector or industry generates part of its electricity internally and the proportion of internally generated electricity changes over time. For example, a decrease in the proportion of electricity that is self-generated will "shift" the heat losses from industry to the electric utility sector, causing an apparent decline in Btu consumed per unit of output, even if industrial energy efficiency has been unchanged.**

The analytic focus of this chapter is on final rather than primary energy use. Mainly for this reason, energy use by the industrial sector has been defined to equal the direct heat content of fuels and purchased electricity used plus the heat equivalent of the energy materials used for non-energy (feedstock) purposes.*** Energy materials used for feedstock represent as much a demand for energy resources as do energy materials used for heat or power. The energy value of purchased electricity is calculated to be its theoretically contained energy–3,412 Btu/kilowatt-hour (kWh)–rather than the total amount of energy used in generating and delivering the electricity, which is more than three times that number of Btu/kWh.

**Self-generation,** it should be noted, is a broad term denoting the generation of electricity by an industrial plant whose primary activity is not the production of electric power. Such self-generation may or may not constitute part of a **cogeneration** operation, in which the energy in the steam used for electricity generation is also used to meet (entirely or partially) one or more other energy needs. Cogeneration can mean the complete use of all the energy within the plant, or the sale of some of the energy or one of the energy forms to an electric utility or an energy end user.

## Determinants of Industrial Energy Use

The total amount of energy used in industry at any one time depends on the level and composition of demand for the products of industry, the relative price of energy, the quantities of capital equipment available for use, the level of technology, Government regulations, and the cost of equipment for improving energy efficiency. Changes in any of these variables will influence the amount of energy used.

Analyzing the determinants individually (i.e., holding the others constant) the following observations have been made:

- **Product demand: In** the short run, total energy use generally increases when demand rises and more goods are produced. Since the production of every kind of industrial commodity requires some energy, only a shift in the composition of demand (product mix) to less energy-intensive commodities can prevent energy use from increasing when output increases. Such product mix changes can result from changes in the economy. For example, there is evidence that in recent years the sharp increase in the price of energy has reduced the demand for energy-intensive products and slowed the

*An approach that avoids the above disadvantage is to measure the energy content of all materials and electricity taken in by the sector or industry and to subtract from it the energy contained in all products shipped. Since this entails the enormous task of determining the energy content of each of the millions of commodity input and output flows, this method has not been used herein.

**The choice between the measures of heat value of purchased electricity is particularly important for the industrial sector because the proportion of electricity used that is self-generated can be significant for the sector as a whole and appreciable for some Industrles. For instance, more than 46 percent of the electric power used by paper and paperboard mills (excluding building paper) in 1979 was self-generated. However, for industry as a whole, the self-generated electricity share has decreased markedly. While such self-generated electric power accounted for 21 percent of electricity used in manufacturing establishments in 1958, it was only 9 percent in 1979. Appropriateness of measurement method hinges on purpose of analysis, the particular Industry group under examination, and the level of disaggregation. Correct analytical treatment of electrical generation heat losses wiIl become more critical if there is rapid growth of cogeneration. This is true whether the electric power is used by the industrial plant or is sold to a utility.

***Use of the narrower definition of the energy content of purchased electricity has another analytical advantage for the present purpose. While the overall measure of energy in purchased electricity is helpful in Indicating the total impact of a sector or industry on the total demand for energy in the economy, it is not a good Indicator of the effects on energy use brought about by changes within the sector or industry, This is because changes in the amount of heat used by external electric utilities to generate each unit of electricity are Incorporated into the energy use totals of the sector or Industry. Average thermal efficiency of electric utilities Improved by nearly one-third between 1947 and 1967, fell a Iittle from 1967 to 1971, and has Since risen slightly, but Irregularly.

growth of energy-intensive manufacturing industries.

- Relative **price of energy:** In production, those processes that use less energy for making a commodity become more economical and attractive when the relative price of energy increases. Another way to reduce energy losses is by instituting more careful housekeeping.
- **Use of capital equipment:** Energy use over the long term can be affected by an increase in the amount of capital equipment. For example, a change from a labor-intensive process to one that is highly mechanical can increase energy consumption. However, capital can be substituted for energy, such as when a furnace or steam pipe is insulated.
- **Level of technology:** An improvement in technology results in a decrease in the amount of one or more inputs needed to produce the same amount of output (holding other factors constant). While energy frequently is one of the inputs reduced, sometimes its use will rise as a result of a technological change. For instance, a new process may economize on labor, yet consume more energy.
- **Government regulations:** Energy use can be affected by Government regulations, particularly those aimed at protecting the environment or worker safety and health. In most cases, additional procedures are required, such as processing of wastes and instituting work area security measures, that entail the use of energy.
- **Cost of equipment for improving energy efficiency:** The cost of equipment for improving energy efficiency can have a direct impact on energy use within an industry. A piece of equipment may return many dollars in savings via decreased energy costs; but if the initial investment is very expensive, the corporation may not have the funds to undertake such a project.

## Qualitative Characteristics of Energy Use

### Capital Intensiveness

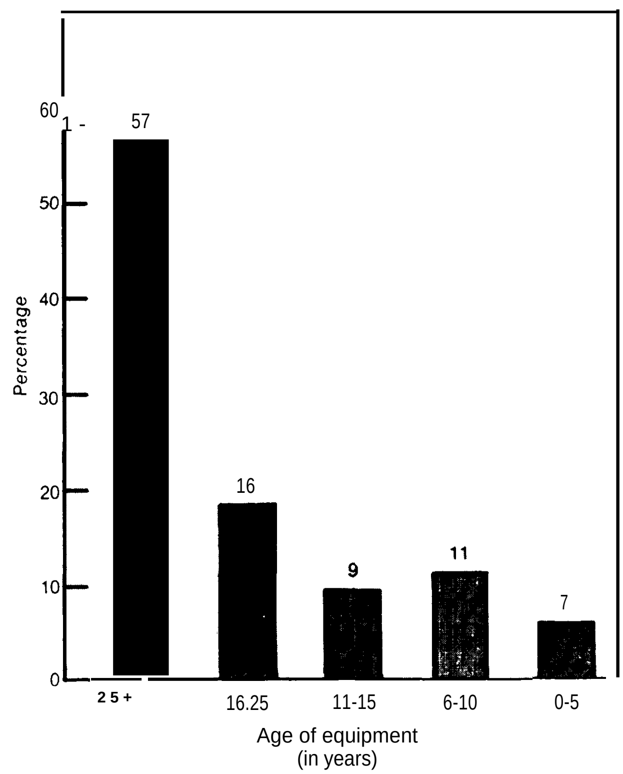
Energy use in any sector is related to the available stock of capital equipment in use. While energy intensiveness is not solely a function of capital intensiveness, the connection is strong. When data on capital equipment per person employed are compared with figures on energy use per unit of output, divisions and industry groups that have high ratios of capital to labor appear to be those with high energy intensity.[2]

In "capital-dominated" industries, increases in overall productivity (which normally means reduced energy intensity) are most likely to come from additions of new equipment or processes.[3] However, because the initial cost of capital equipment is high and the average useful life of capital ranges from 5 to as many as 50 years, replacement of equipment is slow (see fig. 9). This fact limits the rate at which new equipment with dif-

[2]John w. Kendrick and Elliot S. Grossman, Productivity in the *United States, Trends and Cycles* (Baltimore: The Johns Hopkins University Press, 1980).

[3]Bela Gold, *Productivity, Technology, and Capita/* (Lexington, Mass.: D.C. Heath & Co., 1979), pp. 98-100.

**Figure 9.—Overall Age Distribution of Equipment in the Manufacturing Industry, 1975**




SOURCE: John Govoni and Cyr Livonis, "Age of Manufacturing Plants," *Joint Statistical Meetings,* San Diego, Calif., August 1978.

ferent energy-use characteristics can be adopted by industry.

In some cases, improved raw materials result in improved productivity in capital-dominated industries. A notable example is the steel industry, where the use of pelletized iron ore (produced in the mining division) has decreased coke and heat energy requirements.

## Process-Specific Technologies

The processes employed in the output of industrial products are many and diverse. Each of the many industrial substances handled and transformed requires a process suitable to the location of the industrial activity and the commodity's physical state, chemical composition, and final use. For example, some furnaces in the steel industry are used to melt materials to permit further processing, whereas furnaces in brick manufacture are used to harden the product. Because technological change in one process often has little or no applicability to other processes, the rate at which changes in industrial energy use can occur is limited.

## Raw Material Use

In its role as the goods-producing part of the economy, the industrial sector uses large quantities of energy materials primarily, if not exclusively, as feedstocks for products that are not intended for energy purposes. This situation is unique among the major energy-using sectors. The energy materials used as feedstocks by the industrial sector in 1979 had a heat value of nearly 6 Quads, roughly one-fourth of the total industrial energy use.

The use of energy materials for feedstocks is concentrated in manufacturing and construction. Most of such feedstock materials are petroleum products and natural gas. Petroleum-based feedstocks are used mainly in the petrochemical industry–e.g., for industrial organic chemicals and in construction asphalt. Natural gas is a major feedstock for ammonia and fertilizer manufacture.

Most of the substantial amount of coal purchased by the steel industry is classified as a feedstock by the Bureau of the Census because it is processed to produce coke and other byproducts. Coke is essential to the chemical change that occurs when iron ore is changed to molten iron, and it is a source of the necessary heat. In 1981, metallurgical coal with a heat value of approximately 1.4 Quads was converted into coke.

## Use of Captive Energy

A significant proportion of energy used for heat or power by the industrial sector is derived from waste materials or byproducts generated by industrial processes. Examples are exothermic heat generated in chemical reactions, the production of coke oven and blast furnace gases in the steel industry, and the combustion of waste wood in the paper industry.

The energy content of the used "captive" energy may or may not be counted in Department of Energy (DOE) or Census Bureau compilations, depending on the type of energy source. For example, where the energy source is a petroleum product, its full heat value has already been counted by DOE, but not by the Census Bureau in its quinquennial *Census of Manufactures* or the *Annual Survey of Manufactures* reports. If the source is not a conventional industrial energy source (e.g., wood wastes in a papermill), the heat value of the used captive energy is counted by neither DOE nor the Census Bureau. In the first case, the demand for energy sources is known, but there is no information on the part that went for heat or power rather than for incorporation into a product. In the second case, there is no reflection in overall energy use data of this portion of energy use in the economy, even though its existence has an effect on the amount of "conventional" energy consumed. In both cases, some information is missing that would assist analysts in learning about the manner, efficiency, and extent of both conventional and unconventional energy use.

## Shifts in Energy Use Between Sectors

Changes in the relative prices of goods and services over time affect the location of energy use in the economy. Such changes can result even if there has been no change in the composition of demand. Awareness of energy displacement is important to avoid incorrect conclusions about energy conservation in an industry, division, or sector. Many such shifts have occurred. For example, a shift to the mixing of concrete by suppliers, as opposed to builders, has resulted in a shift in energy use from the construction to manufacturing (the ready-mix concrete industry). Rapid growth in fertilizer and pesticide use by agriculture has increased farmers' output relative to energy input, but has added substantially to total energy use in manufacturing. Finally, the expansion of the frozen food industry in manufacturing has decreased the amount of energy used for food preparation in the residential sector. Awareness of such shifts is crucial to proper interpretation of industrial energy use figures.

### Capital Effects and Capacity Utilization

Energy use per unit of output is generally high when the level of production is low. One reason for this is simply the need, at reduced levels of output, to reheat furnaces, ovens, or boilers that have been allowed to cool during exceptionally slack periods. The steel industry provides an especially good example of this effect. During the recession years of 1970 and 1975, energy use per ton of raw steel produced rose 6 and 10 percent respective y.

An exception to this effect is found in industries where plants can be partially or completely shut down if there is a decline in demand and when it is feasible to shut down the least efficient facilities. Such a situation requires a homogeneous product and a comparatively small number of firms in the industry. A

## Quantitative Energy Use Characteristics

### Overall Sector Consumption

Energy directly used by the industrial sector for heat, power, and feedstocks accounts for almost one-third of the total energy used in the United States. In 1981, the heat value of such direct energy use totaled 25 Quads, or 30 percent of the economywide aggregate of 73.8 Quads.

In contrast to the other broad, energy-using sectors, direct energy use by industry has decreased from 40 percent of the U.S. total in 1947, to 30 percent in 1981. This decline was due partly to the decline in the share of the gross national product (GNP) accounted for by the sector.

As shown in figure 10, extrapolating historical trends prior to 1972 would lead to an estimate of 40 Quads of energy use for 1981. However, actual energy use in 1981 was only slightly higher (29 Quads) than in 1972. DOE analysis indicates that a slower growing economy accounted for 4.4 Quads of this difference: the economy went from an annual GNP growth rate of 4.0 percent in 1972 to 2.6 percent in 1981. In addition, the United States now uses a slate of industrial products different from that used in 1972. For example, consumers drive more fuel-efficient automobiles, made of less steel and less petroleum-based plastics. Moreover, U.S. production is now greater in areas such as computers and biotechnology and less in steel production and petroleum refining. This market-induced phenomenon is due, in part, to perceived or anticipated rising energy prices and also to expanding markets in these new areas.

In addition, there is a historical trend toward even more energy-efficient production facilities, Even when energy costs were stable or declining, industrial managers had significant reason to make efforts to conserve energy. Moreover, as manufacturing technology continues to evolve, it becomes more energy efficient. Between 1972 and 1981, the 2.3 Quads of energy saved because of new technology would have been saved even if prices had not increased since 1972,

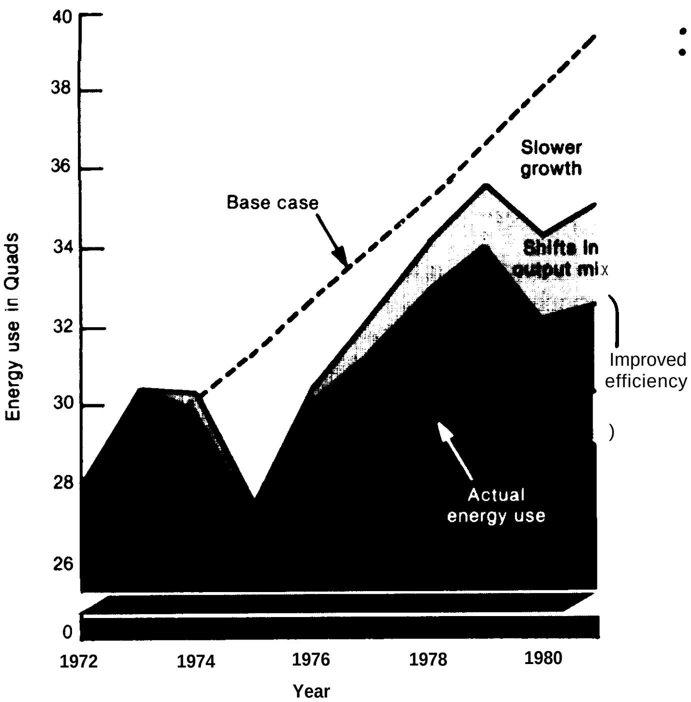
Finally, 1.1 Quads of energy were saved because of efficiency improvements made specifically to existing equipment to counteract the quadrupling of energy prices since 1972.

### Energy Use by Divisions

Energy use by the industrial sector is not proportional to the relative sizes of the divisions in dollar value of output. Just as the divisions are

[4]This discussion of cyclical effects is based on material in J. G, Myers, et al., *Energy Consumption in Manufacturing* (Cambridge, Mass,: Ballinger Publishing Co., 1974); and J. G. Myers and L. Nakamura, *Saving Energy in Manufacturing* (Cambridge, Mass.: Ballinger Publishing Co., 1978).

**Figure 10.—Energy Trends in Industry, 1972-81**




- ***Energy use* in 1981 was down 10.4 Quads from the base case.**
- **These *energy savings* (26%) result from several factors:**
  - — *Slower growth* (4.4 Quads) —Industrial output slowed from 4.% per year to 2.6% per **year after 1972;**
  - — *Shifts in output mix* **(2.6 Quads) —depressed output among large, energy-using industries (steel, cement, chemicals, aluminum, paper) is offset by increased growth in lighter manufacturing (textiles, fabrication of aircraft and machinery parts, computers, and food processing);**
  - — */reproved energy efficiency* **(3.4 Quads)—new technologies and better energy management. Part is due to the** *historical trends (2.3* **Quads) in improving energy efficiency associated with capacity expansion and capital stock turnover; the remainder is due to** *accelerated gains* **(1.1 Quad) in improved efficiency associated with higher energy prices.**

**SOURCE: R. Marlay, Off Ice of Plannlng and Analysis, U.S. Department of Energy. Analysis based on data from the Board of Governors of the Federal Reserve System, the U.S. Department of Commerce, the Energy Information Administration, and on "Industrial Energy Productivity, 1954 -1980," Massachusetts Institute of Technology, Cambridge, Mass.**

diverse, so are the activities and products within each division. The bulk of industry's energy use takes place in manufacturing—the largest division in output. Direct energy use in manufacturing totaled an estimated 19.5 Quads in 1979, or 75 percent of the total for the industrial sector (see table 7). Gross product originating in manufacturing was 76 percent of industrial sector gross product (in 1972 dollars) that same year.

Almost half of the rest of the energy used by industry is accounted for by mining, but mining's share of the sector total is disproportionate to its output. Estimated energy use in mining was 2.7 Quads in 1979, while gross product originating in mining accounted for only 4 percent of the industrial sector's total. Agriculture and construction each used about 1.6 Quads in 1979, or 6 percent each, of total industrial energy use. These divisions' respective shares of sector gross product originating were 8 and 12 percent. The different proportions between energy use and out-

**Table 7.—industrial Energy Use by Division (in quadrillion** Btu)

| Division | 1954 | 1967 | 1972 | 1979 |
|---|---|---|---|---|
| Agriculture. . . . . . . . . . | 0.90 | 1.40 | 1.61 | 1.63 |
| Mining . . . . . . . . . . . . . | 1.27 | 1.78 | 1.99 | 2.68 |
| Construction . . . . . . . . | 0.82 | 1.24 | 1.60 | 1.60 |
| Manufacturing. . . . . . . | 11.78 | 17.62 | 19.76 | 19.54 |
| Total . . . . . . . . . . . . . | 14.77 | 22.04 | 24.96 | 25.45 |

**NOTES: The energy value of purchased electricity is defined hereto be the theoretically contained energy of the delivered electricity—that is 3,412 Btu/kWh.**

**The data shown are estimates and include energy substances used as raw materials. Recent revisions by DOE of energy consumption data have been substantial and make it difficult to reconcile DOE figures on energy use with figures published by the Bureau of the Census for manufacturing.**

**SOURCES: Bernard A. Gelb and Jeffrey Pliskin,** *Energy Use in Mining: Patterns and Prospects,* **Cambridge, Mass., 1979; John G. Myers,** *Industrial Energy Demand, 1976-2000,* **draft report prepared for the General Accounting Office, July 31, 1979; Economics, Statistics, and Cooperative Service, U.S. Department of Agriculture,** *Energy and U.S. Agriculture: 1974 and 1978,* **Washington, D. C., 1980; Tetra Tech, inc.,** *Energy Use in the Contract Construction Industry,* **prepared for the Federal Energy Administration, Feb. 18, 1975; Bureau of the Census, U.S. Department of Commerce, 1977** *Census of Mineral Industries,* **"Fuels and Electric Energy Consumed," February 1981; Energy information Administration, U.S. Department of Energy,** *End Use Energy Consumption Data Base: Series 1 Tab/es,* **Washington, D. C., 1978; Energy information Administration, 1981** *Annual Report to Congress,* **Washington, D. C., 1982; Bureau of Mines, U.S. Department of the Interior,** *Minerals Yearbook, several* **issues, Washington, D, C.; Bureau of Mines,** *Energy Through the Year 2000,* **Washington, D. C., 1972.**

put reflect large differences in energy use per unit of output among divisions.

Much more is known about energy use in manufacturing and mining than in agriculture and construction because of the availability of detailed industry data over an extended time period from the quinquennial *Census of Manufactures* and from the Bureau of Mines industry surveys and *Minerals Yearbook.* In recent years, the *Annual Survey of Manufactures* has provided yearly figures on energy use i n manufacturing.

## Variability of Energy Intensiveness

The energy used per unit of product varies markedly among divisions and industries. Examples of high energy use in relation to output can be found in the following industry groups: primary metals, chemicals, petroleum and coal products, and paper and allied products. Purchased energy use per unit of output by these groups ranged from 39,000 to 57,000 Btu per dollar of value added in 1979, compared with 17,000 Btu for all of manufacturing (see table 8). Together, the five groups accounted for approximately 65 percent of manufacturing's purchased energy for heat and power in 1979, as against 26 percent of manufacturing, valued added.

In sharp contrast, the following four groups together accounted for 40 percent of manufacturing, value added, but only 11 percent of energy use: nonelectrical machinery, transportation equipment, electric and electronic equipment, and fabricated metal products. Energy use per dollar of value added by these groups ranged from 3,400 Btu to less than 6,700 Btu.

Greater differences in energy intensity can be seen at the lowest basis of aggregation—the individual industry (four-digit SIC level). For example, in 1979 purchased Btu (for heat and power) per dollar of value added ranged as high as 332,000 Btu for the lime industry to as low as 5,000 Btu for the motor vehicles and car bodies industry. These differences in energy intensity are important for evaluating prospects for reduced energy use i n the economy by virtue of shifts i n product mix.

## End-Use Profile

Attesting to its diversity, industry uses energy for probably a wider variety of purposes than does any other sector of the economy. Estimates, updated for this report, by the Energy Information Administration (E IA) and other organizations indicate that each of seven different types of energy service account for at least 2 percent of sector use[5] (see table 9).

The most energy-intensive industrial processes entail the direct application of heat to break and rearrange atomic bonds through chemical reactions. Since processes such as smelting, ore beneficiation, cement manufacture, and petroleum refining typically involve large amounts of such

[5]Energy Information Ad m ı nitration (EIA), Department of Energy, *End Use Energy Consumption Data Base: Series 1 Tables* (Sprlng-field, Va.: National Technical Information Service, June 1976), p. 206.

In preparing its data on energy consumption by end use, EIA used only explicit published figures, and made few, if any, estimates, As a result, large quantities of energy use were not categorized by end use, but designated as "other. " The Congressional Research Service has used additional related Information to categorize most of this use in the case of the industrial sector.

**Table 8.—Distribution of Purchased Energy for Heat and Power of Output by Selected Industry Group in U.S. Manufacturing, 1979**

| Industry group | Energy used (Trillion Btu) | Energy used (% of total) | Value added ($ billion) | Value added (% of total) | Energy used per dollar of value added (thousand Btu) |
|---|---|---|---|---|---|
| Paper and allied products | 1,300 | 10.1 | 29.7 | 3.8 | 43.8 |
| Chemical and allied products | 2,889 | 22.5 | 73.4 | 9.5 | 39.4 |
| Petroleum and coal products | 1,245 | 9.7 | 24.8 | 3.2 | 50.1 |
| Stone, clay, and glass products | 1,266 | 9.8 | 24.1 | 3.1 | 52.6 |
| Primary metals | 2,689 | 20.9 | 47.6 | 6.2 | 56.5 |
| Total manufacturing | 12,869 | 100.0 | 772.6 | 100.0 | 16.7 |

**NOTES See note to table 7 regarding energy content of purchased electricity Percentages were calculated from unrounded numbers**

**SOURCE: U S. Bureau of the Census, 1979** *Annual Survey of Manufactures*

**Table 9.—Estimated Distribution of U.S. Industrial Energy Use, by Energy Service, 1978 (percent)**

| Energy service | Manufacturing | Entire sector |
|---|---|---|
| Space conditioning[a] | 2 | 2 |
| Direct heat | 30 | 26 |
| Machine drive | 5 | 13 |
| Vehicles[b] | 2 | 8 |
| Steam | 22 | 16 |
| Electrolytic process | 5 | 4 |
| Raw material | 30 | 27 |
| Other[c] | 5 | 4 |
| Total | 100 | 100 |

[a]Includes space heating and cooling, light, water heating, and refrigeration.
[b]Off highway.
[c]In some cases where no amounts are shown, the small quantities of energy use accounted for by particular energy services have been included in "other."

SOURCES: Energy Information Administration, U.S. Department of Energy, *End Use Energy Consumption Data Base: Series 1* Tables (Springfield, Va.: National Technical Information Service, June 1978); Solar Energy Research Institute, *Building a Sustainable Energy Future,* vol. 2, published by the U.S. Congress, House Committee on Energy and Commerce, April 1981, estimates by the author.

heat, it is not surprising that more than one-fourth of industrial energy use is accounted for by direct heat applications. Because steam is another source of heat, most notably in the manufacture of paper and chemicals, this energy service represents another one-sixth of industrial energy use. Thus, heat of some sort accounts for nearly half of total industrial energy applications. When energy sources used for feedstocks (more than one-fourth of the total) are subtracted, direct heat and steam account for nearly three-fifths of industrial end-use energy demand. Using energy to provide fuel and electrical power for machinery and vehicles is predominant in agriculture, construction, and mining, where it accounts for an estimated 86, 45, and 57 percent, respectively, of energy use in those divisions.

## Trends in Energy Use Per Unit of Output

Overall industrial energy use per unit of output has decreased steadily since the late 1940's, including both before and after the Arab oil embargo of 1973-74.

### Post-World War II to 1972

Between 1947 and 1972, energy use per dollar of real gross product in the industrial sector fell an average of 1.1 percent per year. Also, use of energy per unit of output in manufacturing decreased an average of 0.8 percent per year between 1954 and 1972. Most of this decline was traced to: 1 ) faster energy saving by the energy-intensive manufacturing industry groups compared to other manufacturing industries, and 2) faster output growth by the less energy-intensive industries. Among the energy-intensive manufacturing industry groups, the 8 or 10 largest users (which accounted for half of manufacturing energy use) reduced their energy use per unit of output faster than did the remaining energy-intensive industries.

Within manufacturing, declines in energy-output ratios were the net result of a number of opposing influences. Probably most important was the introduction of new technology that permitted an industry to produce a given volume of product with a smaller quantity of capital, labor, energy, and materials. The introduction of new technology nearly always entailed new or expanded manufacturing facilities. In some cases, improved raw materials aided overall productivity. Labor and energy were frequently the inputs that were economized.

Improvements in management techniques also contributed to the decreases in energy consumption per unit of output. However, such managerial and technological developments were largely incidental to innovations designed primarily to enhance overall productivity. Finally, the shift in production from energy-intensive industries toward those that were less energy-intensive also contributed to the decline in the energy-output ratio for all manufacturing. The former are mainly basic material industries; thus, this shift is part of the long-term development toward higher degrees of fabrication.

In contrast, energy use per unit of output in manufacturing was boosted by an acceleration in the late 1960's in the growth of industries using large amounts of energy-bearing commodities for raw materials—particularly petrochemical feedstocks and natural gas. Such industries included plastics, manmade fibers, and agricultural chemicals. The decline in energy use per unit of output would probably have been steeper without this development.

The preembargo period also saw a drastic shift in the sources of energy used by industry, some of which may well have contributed to the de*cline in* energy use per unit of output. Between 1947 and 1972, the share of industrial energy use accounted for by coal—which burns relatively inefficiently—shrank from 55 to 20 percent. At the same time, shares of natural gas and petroleum expanded from 23 and 19 percent, respectively, to 45 and 25 percent. To some extent, the growth in natural gas and petroleum was attributable to rapid expansion of their use as feedstocks.

Meanwhile, use of electricity by industry grew rapidly, continuing the electrification of the sector that began early in the 20th century. Expansion of electricity use took place mainly from increased purchases of utility electricity, in part because the real price of electricity to industry fell. But self-generated electrical power also grew in absolute terms, though its relative share of the total amount of electricity used by industry fell. Purchases in 1972 were about five times the 1947 level; self-generated electricity was twice the 1947 volume.

Perhaps most notable about the drop in energy use per unit of output in industry between the late *1940's* and early 1970's is that it occurred when the real price of energy was falling.

### Trends Since 1972

The rate of decline in industrial energy use per unit of output has accelerated since 1972. **Sec**tor energy use for fuel and nonfuel uses per unit of output fell an average of 2.4 percent per year between 1972 and 1980, compared with the 1.1 percent decline of the earlier period, The causes of this more rapid decline appear to be a combination of: 1) a decrease in the energy-output ratio within each division, caused both by better housekeeping and by major capital equipment modifications, and 2) a product mix shift to less energy-intensive products. b

At the division level, manufacturing experienced an average annual decline of 3,4 percent per year in energy use per constant dollar of gross product between 1972 and 1979 and, as the larg*est* energy-using division, provided most of the impetus to lower energy use per unit of output in the industrial sector.

Energy use per unit of output in agriculture also fell, but less rapidly. Data for energy use and output in mining indicate a notable rise in energy use per unit of mining output. However, it is possible that difficulties encountered by estimators at the Department of Commerce i n determining gross product originating in mining have resulted in an understatement in mining gross product and therefore an overstatement of energy use per unit of output in 1979.

Analysis of manufacturing energy use during the 1970's reveals considerable energy savings throughout the sector. In many cases, this energy efficiency improvement was assisted by faster output growth, especially in the less energy-intensive industries. Among industry groups, only one (tobacco manufacture) did not experience a decrease in energy use per unit of output between 1971 and 1979 (using Federal Reserve Board production indices to measure output change).[7] Most industry groups achieved overall decreases of more than 30 percent in energy use per unit of output over the 8 years.

Smaller than average reductions in per-unit energy use by the largest and most energy-intensive industries during the 1970's are due to several factors. Slow economic growth and a major recession tended to hold down capacity utilization and, therefore, to boost energy use per unit of output. Slow growth in demand for an industry's products also reduced the rate of infusion of new state-of-the-art plants and equipment and minimized opportunities to incorporate the most energy-efficient, fixed capital, and production methods. Imposition of a variety of worker health and safety and pollution control regulations also had a negative impact on energy efficiency in the industries affected. a

[b]Some analysts have attributed more of the acceleration in the decline in energy use per unit of output by the Industrial sector to the shift to less energy-intensive products than has been done here. See the DOE analysis described in fig. 10. Such a difference in results may be due to d Inferences in the respective methods used and in the data available to and used by the analysts.

[7]OTA calculations based on production indices obtained from the Board of Governors of the Federal Reserve System and the energy use data from *The Annual Survey of Manufactures,* Bureau of the Census, Department of Commerce.

"Edward F. Denison, "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input, " *Survey of Current Business* (Washington, DC.: U.S. Department of Commerce, Bureau of Economic Analysis, January 1978), pp. 21-44.

# INDUSTRIAL ENERGY-RELATED TECHNOLOGIES AND PROCESSES

Certain energy-related, industrial technologies and processes, such as steam generation, transcend any particular industry. The generic technologies discussed in this chapter are technologies which, for the most part, exist today and are used by all four of the case study industries examined by OTA.

Although not a technology, perhaps the most important influence in conserving energy is the corporate energy manager, who is often used in conjunction with an energy review committee. Such an individual who can step back and examine the energy flows in an entire mill, or between mills in a corporation, can often achieve highly cost-efficient energy savings which others with more confined attention have not seen. The fact that this is not a hardware purchase, but rather a commitment of human talent should not disguise its importance as a means of energy conservation. Extensive documentation exists on the rewards attributable to making such a serious corporate commitment to energy conservation.[9]

## Housekeeping

Housekeeping items are numerous. In the area of maintenance and repairs they include weather-stripping, replacement of wornout pipe insulation, improved maintenance of steam traps, and tuning of combustion equipment. Those measures for controlling energy waste range from manually switching off lights, machinery, and other energy-using equipment not in use, to designing and operating production schedules that ensure operation of equipment at maximum efficiency. An example of the latter would be ensuring that furnaces are operated only when their load is fully needed. A large amount of the energy savings by industry during the period 1974-80 were obtained by housekeeping.

[9]See, for example, NBS Handbook 115, *Energy Conservation Program Guide for Industry and Commerce,* Gatts, Massey, & Robertson (eds. ) (Washington, D. C.: U.S. Government Printing Office, 1974).

## Retrofitting

In the context of reducing energy use and increasing energy efficiencies, typical examples of retrofitting would be the installation of computer process and production control systems, combustion control systems on a burner array, an economizer on a boiler, or a variety of other heat exchange equipment designed to capture and use wasted heat.

Retrofits can be highly cost effective, not only because of the energy they save, but also because they often increase the performance level of their host equipment and thereby allow increased production without building new facilities. In this event, a retrofit can leverage much bigger costs elsewhere in the corporation and simultaneously offer the possibility of increasing output. Moreover, the small scope of many retrofit projects gives them an advantage: they are incremental purchases and hence have little associated risk. The cost of a retrofit is often low enough to be accommodated in the discretionary or contingency funds available to many mill managers.

## Computer Control Systems

Two easily distinguished varieties of computer control systems—combustion control and process control—are examples of generic technology that can be bought specifically as an instrument to save energy, as with a combustion controller, or as part of an overall profit improvement program that saves energy in an incidental way, as with a process controller.

### Combustion Control

In the combustion process, a given quantity of fuel requires a fixed and easily measured quantity of air. Having an excess (i.e., nonoptimal) quantity of air or fuel results in either unused air being heated or incomplete combustion of fuel. In either case, the full heat value of the fuel is not captured, and the overall conversion of fuel to electrical, mechanical, or thermal energy is not as efficient as it could be.

The aim of a combustion controller is to maintain the fuel-to-air ratio as close as possible to optimal by controlling the rate at which each is introduced to the combustion chamber. The controller performs its function by measuring the ratio of combustion products found in the exhaust gases. Products of combustion can include oxygen, carbon dioxide, and carbon monoxide. By monitoring ratios of these products, a computer can calculate an optimal air-fuel ratio, and make necessary corrections or adjustments to minimize inefficient combustion.

Modern combustion controllers are electronically based and, apart from being far more accurate than their old mechanical counterparts, are able to act more quickly to correct any imbalances. They are, therefore, far more efficient in their intended operation. Combustion control systems have been extensively applied to industrial operations and are expected to play an even greater role in the future.

### Process Control

Process control is defined here as the computerized monitoring of process variables for the optimization of production. Process controls are almost universally applicable to industry; and although saving energy is not their primary function, it becomes a secondary benefit of the effort to increase overall efficiency and productivity.

Because of the increased speed of industry processes, hand-operated and slow-acting analog controls create inefficiencies. The advent of the microprocessor and of computer control systems has enabled industry to advance the speeds of processes, thereby maintaining higher efficiencies without losing control. Although not adopted universally, the use of process control technologies is expected to increase throughout industry over the next two decades.

*Photo* ***credit:*** *American Petroleum Institute*

Control room at a modern petroleum refinery

## Waste Heat Recovery

Wherever fuel is burned, the products of combustion are a potential source of wasted heat. industrial processes employ a vast variety of fuel-burning equipment; therefore, the recovery of waste heat has major potential for numerous energy conservation programs throughout the industrial sector. The task is to find suitable applications for the waste heat, much of which is at too low a temperature to be used as is.

### Heat Exchangers

Heat exchangers are devices that transfer heat or energy from a high-temperature, waste heat source (e. g., the combustion gases) to a more useful medium (e. g., steam) for low-temperature use. The energy transferred can then be employed within the plant. Heat exchangers take many forms and include heat wheels, recuperators, economizers, waste heat boilers, regenerators, and heat pipes.

The cost of a heat exchanger of any type is often deceptively low, Installation costs are frequently triple (or more) the base price of the unit. Furthermore, maintenance costs can be significant, particularly if there are moving parts (as in a heat wheel), or where the flue gases are corrosive (as when burning high-sulfur oil or coal). In many industrial applications, heat exchangers are usually a more attractive investment when they are purchased as part of the original package of the furnace or boiler.

### Upgrading Energy

Apart from these high-temperature, waste heat sources, industry has a variety of low-temperature and low-level waste heat sources that can only be utilized by upgrading them–i.e., by raising their temperature and pressure. Two technologies for upgrading heat are:

- **Vapor recompression:** By vapor recompression, low-pressure steam is recompressed mechanically to a pressure and temperature that can be used in an industry.
- **Heat pump:** A heat pump converts waste heat into useful energy through a cycle of operations that can be described as a reverse refrigeration cycle.

In both cases energy must be added to upgrade the energy contained in the waste heat sources.

In terms of Btu, low-level waste heat sources would appear to have enormous potential. A substantial percentage of industrial energy input is rejected as low-level heat. However, the economics of recovering these Btu in the form of useful energy through such devices as vapor recompression and the heat pump vary greatly with the origin and quality of the waste heat source, the capital costs of the compressor or heat pump, and the energy cost associated with driving the system. Therefore, although these upgrading steps are technically the same across many industries, some pertinent applications and factors are industry-specific.

## Electric Motors

The use of electricity by industry in 1980 was 2.8 Quads (or three times greater if one includes the electricity generated by utilities burning fossil fuels). Of that, roughly 80 percent was for mechanical drive, which essentially means electric motors. Accordingly, there is a large energy-saving opportunity associated with increasing the efficiency of electric motors. Standard electric motors range in efficiency from between 80 to 90 percent. By increasing the iron and copper content of the core and windings, respectively, energy efficiencies can be improved to beyond 95 percent.

This incremental increase in efficiency may not appear significant at first sight. However, electric motors are almost unique among capital investments in that their capital costs are only a small fraction of their operating costs, even with the added iron and copper content of the higher efficiency motors. For example, an electric motor could use in excess of 10 times its capital cost in energy each year, and the difference between a 90- and 95-percent efficiency could mean an annual energy saving of between 50 and 60 percent of a motor's capital costs. However, the electric motor is a very reliable item of equipment. In normal atmospheric applications it can have a life expectancy in excess of 20 years. Because of this, the replacement of a low-efficient electric motor with its high-efficient counterpart often comes under discretionary spending. Although the replacement of a functioning motor could be economically justified, it would certainly not be mandatory. On the other hand, when an electric motor has reached the end of its useful life, it is common to replace it by a newer, more efficient type.

## Fuel Switching

In U.S. manufacturing, there exists an economic incentive to use one fuel over another when prices differ, In addition, noneconomic factors would also lead a firm to use one fuel over another. Such noneconomic factors are usually related to security of supply or to government regulation.

OTA analysis indicates that there are two trends in fuel switching that will continue for the next two decades. The first trend is toward the use of coal as a primary boiler fuel at industrial plant sites. The second is toward the increasing use of cogeneration facilities in which both electricity (or **perhaps** mechanical and drive power) and steam are produced simultaneously.

### Technology for Converting to Coal

Although switching from natural gas or oil to coal does not usually constitute an improvement in energy efficiency, it may very well be a desirable goal from a national point of view, Coal prices are often one-quarter of the cost of oil in terms of Btu purchased.

Some of the well-documented[10] barriers preventing a smooth and consistent transition from natural gas or oil to coal, however, include the following:

1. Within the corporate plant, switching from natural gas or oil to coal would be of very low priority in the discretionary spending pool unless it could be readily coupled to security of supply.
2. Unless the boilers were originally designed for coal, a complete new boiler plant would be required, including all the coal storage and handling equipment, as well as equipment for ash removal. if existing boilers were still operational, their premature replacement would very rarely make economic sense.
3. The installation of material-handling equipment, as described in (2), above, requires large amounts of space, as does the storage of coal. Such space is often at a premium at most industrial sites.
4. Pollution control technology for coal is extremely expensive and far more complex than that necessary for gas or oil. In fact, natural gas requires no special technology, and, providing that one can purchase low-sulfur oil, all other regulations can easily be met. Even if low-sulfur coal can be obtained, it requires equipment to remove fly ash and particulate. Furthermore, there is now a perceived risk involved in burning coal because of the attention and publicity associated with acid rain.
5. In the large installations, deliveries of coal can involve major capital and space allocations for railroad facilities and sidings. On the other hand, oil and gas for this type of facility can be fed into the plant via pipeline.

Thus, despite the large cost advantage of coal, most of the problems listed above tend to undermine the attractiveness of coal. Some of the newer coal-burning technologies (i.e., fluidized bed combustion or the burning of coal/water mixtures) may reduce these problems. However, until these technologies have actually been proven, there is no way to assess their impacts, and, under the present economic and competitive environment, it will take a long time for coal to make major inroads as an energy source in most industries.

## Cogeneration

Cogeneration is defined as the production of both electrical or mechanical power and thermal energy from a single energy source.[11] In industrial cogeneration systems, fuel is first burned to produce steam. This steam is then used to produce mechanical energy at the turbine shaft, where it can be used directly, but more often is used to turn the shaft of a generator, thereby producing electricity. Although the steam that leaves the turbine is at a lower temperature and pressure than that which entered, it still has sufficient thermal energy to perform the heating and mechanical drive duties required throughout the plant. In contrast to cogeneration systems, conventional industrial power systems produce their own thermal energy at the plant site but usually buy their electrical power from a utility.

The principal technical advantage of a cogeneration system is its ability to improve the efficiency of fuel use. In producing both electric and thermal energy, a cogeneration facility uses more fuel than is required to produce either electrical or thermal energy alone. However, the total fuel required to produce both types of energy in a cogeneration system is less than the total fuel required to produce the same amount of power and heat in separate systems. Because it produces two energy forms, a cogenerator will have less electrical output from a given amount of fuel than will a comparable powerplant. However, when steam and electrical efficiencies are summed, the cogenerator will achieve overall fuel use efficiencies 10 to 30 percent higher than the sum of separate conventional energy conversion systems.

Cogeneration does not easily fit into any of the previously described categories such as retrofitting or housekeeping, and although presented in this section, is not entirely a generic technology.

[10] *The Direct Use of Coal: Prospects and Problems of Product/on and Combustion* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-E-86, April 1979).

[11] A more detailed discussion of promising cogeneration technologies and their potential Impacts can be found in: *Industrial and Commercial Cogeneration* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-E-1 92, February 1983).

Cogeneration is really a new name for an old and proven practice. Around the turn of the century, industry produced more than 50 percent of the electricity generated in the United States. By 1950, only 15 percent of the U.S. electricity was produced by cogeneration systems in large on-site industrial plants; by 1970, this figure had dropped to less than 5 percent.

Historically, in order to justify a cogeneration system economically and technically, a plant either had to have a balanced need for thermal and electrical or shaft power that was congruent in both time and amount (e.g., the peak requirement for electricity and steam had to be coincident, and their load profiles similar). If such balance and congruence were not present, the system had to be able to distribute excess electricity to other sites or to purchase backup electricity from the local utility. However, few industrial processes had power needs that were this balanced. Moreover, systems that sold electric power were subject to regulation as utilities, and backup power often was more expensive than was regular electrical service. Thus, throughout this century, as electricity from utilities became progressively cheaper, industry found other uses for its capital, and the use of cogeneration by industry declined.

Now, however, the picture has changed, both from an economic and legislative standpoint. In economic terms, the cost of a new, large, utility generating plant increased in recent years to well over $1,000/kW. Furthermore, utilities have been affected by the massive increases in energy prices. The combined effects of increased capital and operating costs have increased the attractiveness of cogenerating facilities once again. In addition, Congress has passed the Public Utility Regulatory Policies Act (PURPA, Public Law 95-61 7), which mandates that utilities purchase the excess electrical energy generated by a cogeneration facility and provide backup service at a reasonable rate. This situation alleviates the necessity of a rigorous energy balance within the plant and allows the cogenerator to retrieve some of its capital expenditure through the sale of electricity to a utility or the purchase of electricity from a utility.

The economic key to cogeneration is the utilization of the waste heat from the cogeneration process, a potential not usually available to a utility. A high level of efficiency for a utility operation would be on the order of 35 to 37 percent, whereas an industrial cogeneration operation may reach an overall efficiency in excess of *70* percent.

Although most of the regulatory problems associated with the sales of industrially cogenerated electric power have been removed by PURPA, industry is unlikely to rush to make the significant new investments required for such operation. Examples of the disincentives facing industry are the following:

1. The environmental implications of cogeneration can be a problem to industry, although they are sometimes overlooked in discussions of the benefits from cogeneration. There is no automatic way for a potential industrial cogenerator to get regulatory approval for the emissions its additional use of fuel will generate. Even though incremental electrical energy will be made available at perhaps half the emission rates of the utility's powerplant, the industrial emitter gets no credit for this improvement. Instead, the emissions would be charged directly and entirely to the industry.
2. How the financial returns from cogenerated electrical energy can be predicted is still uncertain. There has been considerable publicity about the "high" prices (from 5¢ to perhaps even lO¢/kWh) that a utility will have to pay cogenerators and other producers of electricity for the energy that the utility has been able to "avoid" generating or purchasing from the grid. But the situation is not this simple. In many areas (e. g., where utilities have excess capacity or low-cost generating plants), the rates for purchases of power from cogenerators maybe as low as 1¢/kWh.
3. Achieving cogeneration efficiencies at the cost of reducing utility coal use and increasing industrial use of petroleum-derived fuels, would probably not be desirable if the primary goal of national energy policy were net oil savings.

4. Finally, and this may in many instances be the ultimate consideration, even a very attractive cogeneration project may not meet industry management's exacting requirements for the short paybacks and high rates of return that are used to evaluate all projects seeking a share of the hard-pressed, companywide capital budget.

### Product Mix Shift

As energy costs increase or uncertainties prevail over future fuel costs and supply, industries will almost automatically, and on an evolutionary basis, move to minimize these costs, risks, and uncertainties. One method of achieving this is *to* manufacture existing product lines with less process energy through the introduction of more efficient technology.

However, three other alternatives are also available. First, a company could cease manufacturing products that are energy-intensive and put capital to work instead in other spheres of business and industry. For example, Japan, which is having great difficulty in competing with U.S. manufacturers of aluminum and paper, may take measures to secede from these businesses entirely.

Second, a company could develop and manufacture new products that use less energy, yet compete with the old energy-intensive product. An obvious example is the small automobile in competition with the large automobile. Even within this broad category are competing considerations. For example, in the car itself, aluminum and plastics readily replace other metals, such as steel. Arguments that the energy intensity associated with making one product is more desirable than that used for making another product are not really conclusive. Examples include debates about which packages are less energy-intensive—i.e., the glass bottle v. the plastic bottle or the aluminum can v. the steel can. In the final analysis, the marketplace, which considers many other costs besides energy, determines which product wins or loses.

The third course of action occurs when the energy used to make a final product is shifted away from the manufacturing facility to the user of the product, An example of this can be found in the petroleum refining industry. Although less refined gasolines require less energy to produce, they burn less efficiently in automobiles, thereby lasting fewer miles per gallon and increasing the energy cost of transportation. The refinery has essentially shifted part of its energy losses to consumers using these products.

The measurement and quantification of the impact on energy conservation by product shift and product change is beyond the scope of this report. However, it should be noted that over time, these changes almost will inevitably take place to an extent that products and even whole industries could radically contract and disappear.

## POLICIES THAT AFFECT INDUSTRIAL ENERGY USE

### Existing U.S. Industry Energy-Related Legislation

During the 1970's and early 1980's, Congress enacted several major laws that affected industrial use of energy. The general goals of these measures were to reduce oil imports, to encourage domestic production of fossil fuels and the development of nuclear and alternative energy sources, and to reduce energy demand through conservation and energy efficiency improvements. Incentives to meet these goals fell into three general categories: 1) pricing mechanisms, *2)* regulations, and 3) financial incentives. In addition, DOE conducts several programs designed to study industrial energy use and ways to improve energy efficiency in industry.

### Pricing Mechanisms

Oil and natural gas pricing issues dominated congressional energy debate in the 1970's. The difference between domestic oil prices and higher world energy prices was significant and had to be resolved. After a year-long debate, the Energy Policy and Conservation Act (EPCA, Public Law

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94-1 63) was enacted in December 1975. The law provided for the eventual decontrol of oil after September 30, 1981; however, mandatory Federal oil price controls were continued until June 1, 1979, EPCA gave the President authority to continue, modify, or remove the controls after that date. In April 1979, President Carter submitted to Congress his plan, later approved by Congress, to phase in oil decontrol to cushion consumers from rising prices. Oil decontrol proponents believed higher prices would encourage domestic oil production and discourage use while advocates of price control were concerned that higher domestic oil prices would contribute to inflation and burden consumers without providing commensurate new supplies.[12]

To accompany oil decontrol, the Crude Oil Windfall Profits Tax Act (WPTA, Public Law 96-223) was passed in April 1980. Designed to capture some of the windfall profits that oil companies would realize from decontrol, this new tax was levied only on the difference between the base price (ranging from $12.81 to $16.55) and the actual selling price of a barrel of oil. The tax rate varied from 30 to 70, depending on the type of oil, the date the well was tapped, the method of production, and the size of the producer.[13] To date, total revenues collected from the windfall profits tax amount to $28.1 billion ($3.7 billion in fiscal year 1980, $13.8 billion in fiscal year 1981, $10.6 billion in fiscal year 1982). These revenues have been added to general U.S. Treasury funds and not to specific energy-related or transportation projects. On January 28, 1981, President Reagan lifted price and allocation controls on gasoline and crude oil.

For natural gas, the Natural Gas Policy Act (NGPA, Public Law 95-621) provided for continued controls indefinitely on most natural gas contracted for prior to 1977, thus avoiding a sudden windfall for producers. The act further specified that price controls on new gas and certain intrastate gas be lifted entirely by 1985 and that gas from certain onshore wells be deregulated in July 1987. NGPA also provided for incremental pricing, thus placing the initial burden of gas price deregulation on industrial customers. The incremental price is equal to the price of newly discovered natural gas plus regulated transportation costs. This industrial gas price is mitigated through a ceiling determined by regional alternative fuel oil prices for either number 2 or number 6 fuel oil.

The Federal Energy Regulatory Commission (FERC), which administers NGPA, is now considering raising old natural gas* prices. FERC plans to issue a Notice of Inquiry that will explore whether NGPA fosters market ordering problems, such as unequal distribution of gas among interstate and intrastate pipelines, and whether such problems can be alleviated by raising the price of old gas. The FERC staff has suggested that higher prices would eliminate the cushion of price-controlled gas now enjoyed by interstate pipelines. The record developed during the Notice of inquiry could be used as a basis for future FERC rulings.[14]

On February 23, 1983, the administration submitted to Congress a proposal to eliminate all natural gas price controls and enable pipelines and producers to abrogate long-term contracts that are believed to be keeping prices high. In addition to the administration proposal, several alternative proposals have been introduced. Legislative debate has focused on the decontrol of old gas. Decontrol, opponents argue, means higher rates for homeowners who cannot easily switch to other fuels. Also, there is concern that rising gas prices could prompt industrial and utility users to switch to oil. Because gas prices, in some areas, have surpassed industrial fuel oil, switching has already begun to occur. However, proponents argue that eliminating all controls would encourage the production of old gas and cause old gas prices to increase and new gas prices to decrease.[15]

[12] *Energy Policy,* 2d ed. (Washington, D. C.: Congressional Quarterly, Inc., March 1981), p. 25.
[13] 1 bid., p. 224.

*Old gas is that which was discovered before 1977, and whose price is federally controlled.
[14] *Inside Energy* (New York: McGraw Hill, April 1982), PP. 7-8.
[15] Congressional Quarterly Weekly Report, "Natural Gas Prices: Ready for the Free Market?" vol. 41, No. 9, Mar. 5, 1983, pp. 443-447.

## Regulations

The Government can also intervene in the energy marketplace through regulation. in the industrial sector, Government policies seek to promote the switch from oil and natural gas to coal or renewable resources. Since 1974, the Federal Government has administered coal conversion programs under provisions of the following legislation: EPCA, the Environmental Supply and Environmental Coordination Act (ESECA, public Law 93-319), and the Powerplant and Industrial Fuel Use Act of 1978 (FUA, Public Law 95-620).

ESECA prohibited any powerplant or major fuel-burning installation from burning natural gas or petroleum as a primary fuel source if the plant or installation had the capability and necessary equipment to burn coal. EPCA expanded the authority of the Federal Energy Administration to order major powerplants and fuel-burning installations to use coal instead of oil and gas. FUA further modified and expanded coal switching programs and established new regulatory policies for converting industrial users of oil and natural gas to coal. Under FUA, new facilities may not burn oil or gas until the owners demonstrate to DOE that an exemption is justified. Also, FUA prohibited the burning of natural gas in existing powerplants from 1990 on and restricted its use prior to then. However, a full range of temporary and permanent exemptions was established.[16]

The omnibus Budget Reconciliation Act of 1981 (Public Law 97-35) made changes in FUA. It repealed the general prohibition against burning gas in existing powerplants and withdrew the authority of DOE to prohibit burning oil/natural gas in existing powerplants if the plant were capable of using coal or alternative fuels. Instead, the law allows a utility to certify to DOE whether a powerplant is capable of burning coal/oil or coal/gas and gives DOE authority to prohibit the burning of oil/gas in such plants as certified.

The effectiveness of coal conversion programs is questionable for a number of reasons. The cost of fuel conversion is staggering, and it may be impractical to retrofit some plants. Capital constraints will stretch the time for completion even further. And, while coal is cheaper than oil on a Btu basis, it is not necessarily a cheap fuel when transportation, handling, and pollution control costs are included. In addition, coal-fired boilers are more expensive to purchase than are oil-fired boilers. This reality could be a deterrent to greater coal use, particularly in smaller companies that do not have access to the capital necessary to buy new boilers or to retrofit old ones. In addition, exemption provisions of the law still allow companies to continue burning oil and gas. A company can petition for an exemption for a variety of reasons: air quality, site limitations, and cost.

Another law that can affect energy use in the industrial sector is PURPA. PURPA is intended to encourage the production of power by means of cogeneration and the use of renewable resources, primarily by removing the principal barrier to electric power generation—market entry. Prior to PURPA, utilities were often reluctant to purchase cogenerated electricity at a rate that made grid-connected cogeneration economically feasible. Some utilities charged very high rates for providing backup service to cogenerators (for that electricity that cogenerators could not provide for themselves), With PURPA, utilities must purchase from and sell power to cogenerators and small power producers at economically justified and equitable rates. However, not all cogenerating facilities qualify for the PURPA benefits. A qualifying cogenerating facility* must meet FERC requirements for fuel efficiency, reliability, and the like. Presently, the potential size and structure of the market for cogeneration and small power production is largely unknown.

The U.S. Supreme Court recently upheld the FERC regulations implementing PURPA that require: 1 ) utility rates for purchases of cogenerated power to be based on the utility's "full avoided cost, " * * and 2) utilities to interconnect with cogenerators and small power producers. A Federal Court of Appeals decision had found

[16] Congressional Research Service, *The 9.5th Congress and Energy Policy,* prepared for the House Subcommittee on Energy and Power, January 1979, p. 13.

*A cogenerating facility, as defined by the law is one that produces both electric energy and steam, or other forms of useful energy (such as heat), which are used for industry, commercial heating, and cooling.

**The cost of power generated by conventional means that is avoided or replaced by power from alternative energy technologies.

that full avoided cost pricing deprives other utility ratepayers of any share of the benefits and that the FERC interconnection requirement violated other provisions of the Federal Power Act. '[17] The Supreme Court ruled that, while full avoided cost pricing would not directly provide any rate savings to consumers, it would provide a significant incentive for the development of cogeneration and small power production, and ratepayers and the Nation as a whole would benefit from the decreased reliance on scarce fossil fuels through the more efficient use of energy. The Supreme Court also held that FERC's authority under PURPA is adequate to promulgate rules requiring utilities to interconnect with cogenerators and small power producers.

In an earlier decision, the U.S. Supreme Court upheld the constitutionality of the PURPA requirement that utilities buy power from cogenerators and small power producers and upheld the provision that exempts these facilities from regulation as electric utilities. '[18] These aspects of PURPA had been declared unconstitutional by a Federal district court on the grounds that they exceeded the scope of the power granted to the Federal Government under the U.S. Constitution.[19]

## Financial Incentives

Financial incentives, such as tax credits and accelerated depreciation measures, can be directed toward encouraging the use of coal or alternative energy sources and the adoption of conservation projects. Since the Arab oil embargo, the political climate has generally been favorable to the use of financial incentives. Opposition to these measures was not directed at the concept, but at the amount or timing of the incentive. Some critics argued that the tax credits proposed were not strong enough to affect energy conservation efforts or to compensate for the increased capital outlay and technological risks associated with greater coal usage. Others argued that tax credits involve the Government in the industrial decisionmaking process too heavily. What finally emerged from this congressional debate were several laws that provided a number of financial incentives to industry: the Energy Tax Act of 1978 (ETA, Public Law 95-618), WPTA, and ERTA.

ETA provided a 10-percent business investment credit for: 1 ) specified equipment, such as boilers that use coal or alternative fuels; 2) heat conservation; and 3) recycling and shale oil equipment. This credit could be applied to equipment placed in service between October 1, 1978 and January 1, 1983. At the same time, the law denied a tax credit and granted a rapid depreciation allowance for early retirement of oil- and gas-fired boilers. ETA also encouraged the production of additional fuel supplies, particularly natural gas, by providing a tax credit for equipment used for the production of natural gas from geopressurized brine.

WPTA increased the tax credits for solar, wind, and geothermal equipment from 10 to 15 percent and extended to 1985 the cutoff for granting credits. Also, the law provided a tax credit equal to 10 percent of the cost of cogeneration equipment and extended the tax exemption for industrial development bonds to bonds used to finance facilities that produce energy from renewable resources, as long as the facility was State-owned, backed by sufficient taxing authority, and eligible for financing by general obligation bonds,

One of the most important tax initiatives for industry is ERTA. This law simplified the tax code for depreciation, replacing all capital retirement categories with just four: 3 years for vehicles; 5 years for most machinery and equipment and single-purpose agricultural structures, petroleum storage facilities, and public utility property with a life expectancy of 18 years or less; 10 years for recreational facilities and park structures, mobile homes, and qualified coal conversion property and other public utility property with a life expectancy of 18.5 to 25 years; and 15 years for depreciable real property and public utility property with a life expectancy of 25 years or more, Also, the law encouraged investment in both new and used property placed in service after 1980 by establishing new credit rules: 6-percent credit

[17] *American Electric power Service Corporation* v. *FERC* (675 F.2d 1226 (D.C.Circ. 1982), cert. granted in Case Nos. 82-34 and 82-226 (Oct. 12, 1982).

[18] *Federal Energy* **Regulatory** *Commission* v. *Mississippi,* ____ US. ____, 102 S. Ct. 2126 (1982).

[19] *Mississippi* v. *Federal Energy Regulatory Commission* (unreported opinion, U.S. District Court for the Southern District of Mississippi).

applies to qualified property in the 3-year depreciation class and 10 percent applies for all other qualified property. The investment credit carryover period is extended to 15 years for credits arising in taxable years ending after 1973. In addition, ERTA provided a 25-percent tax credit for research and development (R&D) expenditures paid or incurred in carrying on a trade or business, rather than in connection with a trade or business. Eligible expenditures include supplies used in conducting research and wages to employees performing the research. Furthermore, ERTA reduced the tax on newly discovered oil, and decreased the credit allowed where the cost of energy savings is excessive or where capacity increases as energy is conserved.

Since ERTA shortened the period in which businesses could write off investments, companies could deduct larger amounts each year from their corporate income taxes, thus lowering tax bills and presumably encouraging investment. Critics, however, point out that accelerated depreciation would favor large businesses and would affect individual industries very differently. Furthermore, accelerated depreciation would substantially increase certain types of distortions that exist in present law—particularly those that favor equipment over structures. They also point out that accelerated depreciation will cost the U.S. Treasury billions of dollars in lost revenues. Proponents, on the other hand, say the act simplifies tax laws and will stimulate the economy, increase productivity, and moderate inflation.[20]

ERTA also liberalized earlier leasing rules to promote the sale of tax benefits—both investment credits and depreciation deductions.

Under these new leasing regulations, a corporation who (because of small or nonexistent tax liabilities) is unable to make use of a property's depreciation and tax credits can sell the property and its associated income tax credits to another corporation, and then immediately lease the property back for continued use. The original owner, now a lessee, receives a downpayment and a note for the balance. The new owner, now a lessor, receives payments for rent and makes payments for principal and interest on the outstanding note. Since the property never leaves it original site, and the rental and debt payments are equal, the net effect is that the original owner of the equipment has sold its unusable tax and depreciation credits for the dollar amount received as a downpayment.[21]

In an alternative third-party safe harbor lease arrangement, the lessee is not the actual owner of the property. The new owner purchases the property from the actual owner and then leases it to the lessee at an annual rent that is lower by the tax benefit amount associated with the property,[22]

The U.S. Treasury reported that the value of leased property in 1981 totaled $19.3 billion. About 84.5 percent of the tax benefits from leased property went to the lessee, while 14.2 percent was retained by the lessor. The remaining 1.3 percent covered transaction costs to third parties.[23]

The Tax Equity and Fiscal Responsibility Act of 1982 (TEFRA, Public Law 97-248) modified the safe-harbor leasing provisions of ERTA with respect to eligibility requirements, eligible property, ACRS deductions, investment credits, and lessee/lessor limitations.

Under prior law, the term of a safe-harbor lease could not exceed the greater of 90 percent of the useful life of the property or 150 percent of the average depreciation range (ADR) midpoint life of the property. Under the new law, the lease term cannot exceed the greater of the recovery period of the property or 120 percent of the ADR midpoint life. A second change brought about in TEFRA is that public utility property is no longer eligible for safe-harbor leasing. A third change is that only 20 percent of an investment tax credit (ITC) for property in a safe-harbor lease is allowable in the first taxable year and **20** percent in each of the four succeeding taxable years. previously, 100 percent of an ITC was allowable when the property was placed in service. Fourth, a lessor is not allowed deductions or credits from

[20]Congressional Research Service, "The Capital Cost Recovery Act: An Economic Analysis of 10-5-3 Depreciation," Jan. 28, 1980, p. 2.

[21]U.S. Department of Treasury, Office of Tax Analysis, *Preliminary Report on Safe Harbor Leasing Activity in 1981,* Mar. 26, 1982, p. 2.

[22]Ibid., p. 1.

[23]Ibid.

safe-harbor leases to the extent those deductions or credits reduce its income tax liability by more than 50 percent. Finally, the law repeals safe-harbor lease provisions for leases entered into after December 31, 1983.

### The Industrial Energy Conservation Program

The DOE Industrial Energy Conservation Program focuses on improving the energy efficiency of the most energy-intensive processes used in the U.S. industrial sector and on utilizing waste heat from these processes. The DOE Office of industrial Programs administers this program, which is divided into four subprograms.

1, The **Waste Energy Reduction Program** focuses on improving energy efficiency and on substituting abundant for scarce fuels in processes that are common to many industries. Activities within this program include R&D for waste heat recovery and for combustion efficiency improvements.
2. The Industrial Process Efficiency Program focuses on increasing energy efficiency in the most energy-intensive industries. The areas of activity include cost-shared research, development, and demonstration (RD&D) efforts in steel, paper, aluminum, and textiles. Specific projects include a dewatering process development for pulp and paper, the identification of energy conservation potential in the chemicals and petroleum industries, and the continuous casting and hot inspection of steel ingots.
3. The **Industrial Cogeneration Program** focuses on improving and implementing advanced cogeneration systems that offer large energy savings, while minimizing oil and gas consumption.
4. The **Implementation and Commercialization Program** focuses on stimulating new as well as existing, but underutilized, energy conservation technologies in the industrial sector. An important activity of this program is the industrial energy efficiency reporting program established by EPCA. That act directed DOE (then the Energy Research and Development Administration) to rank the top 10 energy-consuming industries and establish voluntary efficiency-improvement targets for each and a system for reporting annual progress. The National Energy Conservation Policy Act of 1978 (NECPA, public Law 95-61 9) expanded the reporting requirements of the program to include all industries using 1 trillion Btu per year. This program was one of the Government's earliest efforts in industrial energy conservation and helped achieve a higher visibility for conservation.

The future of the Industrial Energy Conservation Program is questionable. The Reagan administration has recommended that Federal industrial energy conservation programs be curtailed. Also, several bills were introduced in the 97th Congress to dismantle or eliminate DOE. If that were to occur, it is not known whether the Industrial Energy Conservation Improvement Program will be shifted to another agency.

## FOREIGN INDUSTRIAL ENERGY USE AND POLICY

A useful context in which to view U.S. industrial energy use is within comparable energy use by industries in other developed nations. * If interpreted carefully, such comparisons can indicate the potential for U.S. energy productivity improvements in the future and help identify policies that can facilitate such improvement.

Total industrial energy and oil use by seven international Energy Agency (IEA) countries in 1973 and 1979 are shown in table 10. * Based on ratios of energy use to per capita income, GNP, or gross

"Industrial energy use data are readily available only for IEA countries and not for other industrial nations such as those in South America. Hence, this discussion of comparative energy use will focus on IEA countries.

***IEA was established in November 1974 within the framework of the Organization for Economic Cooperation and Development** (OECD) to implement an international energy program.

**Table 10.-Industrial Energy and Oil Use by Representative IEA Countries, 1973 and 1979 (millions of barrels of oil equivalent)**

| | 1973 | | 1979 | |
|---|---|---|---|---|
| Country | Total use | Oil use | Total use | Oil use |
| Australia | 135.3 | 50.6 | 177.2 | 52.8 |
| Canada | 352.9 | 162.0 | 458.8 | 156.9 |
| West Germany | 676.8 | 344.5 | 654.2 | 274.1 |
| Italy | 386.5 | 234.6 | 344.2 | 164.2 |
| Japan | 1,084.7 | 644.3 | 1,130.9 | 687.6 |
| Sweden | 122.8 | 67.4 | 105.5 | 46.2 |
| United Kingdom | 510.7 | 272.7 | 473.1 | 221.4 |
| United States | 3,452.2 | 939.0 | 3,257.8 | 1,172.8 |
| IEA total | 7,503.6 | 3,136.6 | 7,465.2 | 3,195.1 |

SOURCE: Energy *Conservation: The Role of Demand Management* in the *1980's,* International Energy Agency, 1981.

domestic product (GDP), the United States is a highly energy-intensive nation and has been for many years.* In fact, among the developed Western nations and Japan, only Canada is more energy-intensive than the United States.

This fact has prompted speculation that the United States could shift to significantly reduced levels of energy use without adverse impaction economic activity. However, studies carried out at Resources for the Future (RFF)[24] point out that intercountry comparisons are complex and that "energy/GDP ratios taken by themselves are at best only a partial indicator of energy conservation potential among countries or of progress in energy conservation over time. "[25] Specifically, RFF points out that careful attention must be paid to differences in composition of economic output, the structure of fuel supply, the vintage of energy-using equipment, energy prices, differences in geography and tastes, and the relative energy intensiveness of a wide range of activities. The RFF study concluded that approximately 40 percent of the difference between the higher U.S. energy/GDP ratio and the lower foreign ratios could be attributed to such U.S. structural characteristics as the large size of the United States and its dispersed population patterns. About 60 percent of the difference arises from energy intensity differences in specific applications. For example, energy use per unit of output in a number of manufacturing activities is higher in the United States than in Europe (see table 11). Evidence is accumulating that, in substantial part, such differences are due to the historically higher energy costs seen by foreign industry. European energy prices have generally been held above market levels through taxation, while in the United States they were held down through the use of controls from 1971 through early 1981.

Under sharp increases in average real energy prices paid by industrial users since 1973, overall industrial energy use in the 21 IEA countries evolved as shown in table 12. While industrial

*For most countries the difference between gross domestic product (GDP) and gross national product (GNP) is relatively minor. Energy-to-GDP ratio is most often used for energy comparisons because GDP reflects only a nation's domestic economic activity, excluding income derived from overseas enterprises and investments, and is therefore the more appropriate national accounts measure to which to relate a nation's domestic energy consumption. The U.S. GDP is virtually identical to U.S. GNP. For some nations the GDP may be as much as 5 percent below the GNP.

[24] Joel Darmstadter, Joy Dunkerly, and Jack Alterman, "HOW Industrial Societies Use Energy: A Comparative Analysis" (Baltimore, Md.: The Johns Hopkins University Press, 1977).

[25] Joy Dunkerly, "Energy Use Trends in Industrial Countries: Implications for Conservation, " *Energy Policy,* June 1980.

**Table 11 .—Comparative Energy Efficiencies of Industrial Processes in Representative IEA Countries[a]**

| Country | Crude steel | Pulp and paper | Petroleum products |
|---|---|---|---|
| Canada | 102 | 116 | 200 |
| Italy | 62 | 59 | 50 |
| Japan | 94 | 88 | 51 |
| Sweden | 73 | 84 | 54 |
| United Kingdom | 88 | 108 | 81 |
| United States | 100 (543) | 100 (579) | 100 (90) |
| West Germany | 60 | 76 | 89 |

[a] Relative 1975 consumption in Btu per ton of product; U.S consumption defined as 100 in all cases. Actual U S consumption is 104 Kcal/ton of product shown in parentheses.

SOURCE: "Energy TOPICS: A Periodic Supplement to IGT Highlights" (table 7), Institute of Gas Technology, Apr. 11, 1977

**Table 12.–Changes in Industrial Energy Consumption in IEA Countries Between 1973 and 1978**

| Energy carrier | Iron and steel | Chemicals | Petrochemicals | Other | Nonenergy uses | Total industry |
|---|---|---|---|---|---|---|
| ***Absolute change:*** [a] | | | | | | |
| Oil | –95.3 | +51 .3 | + 102.6 | –58.6 | +29.3 | + 36.7 |
| Gas | –44.0 | +22.0 | —b | –205.2 | — | –227.2 |
| Electricity | +7.3 | –22.0 | +51.3 | +36.7 | — | + 73.3 |
| Solid fuels | – 175.9 | +7.3 | — | –73.3 | — | –249.2 |
| Total | –307.9 | +58.6 | + 153.9 | –300.4 | +29.3 | –366.5 |
| ***Percent change:*** | | | | | | |
| Oil | *–36.2* | *+28.2* | *+ 14.2* | *–4.9* | *+4.6* | +1.2 |
| Gas | *–20.3* | +11.2 | — | *+ 14.3* | — | *– 12.6* |
| Electricity | +4.1 | –9.5 | +854.9 | +5.2 | — | +7.0 |
| Solid fuels | –18.8 | +19.9 | — | –14.1 | — | +17.0 |
| Total | –19.5 | +10.0 | +21.0 | –7.9 | +4.4 | –4.9 |

[a] In millions of barrels of oil equivalent.
[b] — indicates negligible change.

**SOURCE: Energy** *Conservation: The Role of Demand Management in the 1980's,* **International Energy Agency, 1981.**

production increased by 8.3 percent between 1973 and 1978, total energy use decreased by 4.9 percent. Oil use rose slightly (l.9 percent), mainly as a result of increases in oil use in the petrochemical and chemical industries.

Looking ahead, primary fuel use is expected to increase 36 percent between 1985 and 1990, while oil use is expected to rise only 4 percent, according to IEA projections (see table 13). However, fuel use in individual countries varies considerably. For example, while industrial oil use is expected to decrease in the United States and in four other IEA countries, it is expected to stay level or increase in 16 others.

## National Programs To Spur Industrial Energy Conservation

IEA countries generally identify energy prices and taxes as the most important targets of industrial energy conservation programs because of industry's sensitivity to increased costs. Thus, almost all IEA countries have introduced a range of other measures to complement the effects of increased energy prices. These measures vary from country to country, reflecting different social philosophies and economic conditions. Some countries place primary emphasis on voluntary and incentive measures, while others rely on mandatory programs. As summarized by IEA,

**Table 13.-Projected Trends of Industrial Energy and Oil Use in Selected IEA Countries Through 1990[a] (millions of barrels of oil equivalent)**

| | 1985 | | 1990 | |
|---|---|---|---|---|
| Country | Total use | Oil use | Total use | Oil use |
| Australia | 230.6 | 53.6 | 268.3 | 54.2 |
| Canada | 557.4 | 146.6 | 640.9 | 137.8 |
| West Germany | 704.6 | 274.1 | 741.0 | 271.2 |
| Italy | 404.3 | 160.5 | 441.1 | 140.7 |
| Japan | 1,500.6 | 796.8 | 1,882.6 | 841.5 |
| Sweden | 140.8 | 63,8 | 151.0 | 54.2 |
| United Kingdom | 531.6 | 245.6 | 564.6 | 245.6 |
| United States | 3,553.2 | 1,048.2 | 3,940.0 | 945.6 |
| Total for all 27 IEA countries | 8,801.8 | 3,327.1 | 10,088.1 | 3,319.0 |

[a] Includes nonenergy uses.

**SOURCE:** *Energy Conservation: The Role of Demand Management in the 1980's,* **International Energy Agency, 1981**

the most important measures that have been adopted so far in IEA countries are:

- fiscal and financial incentives, to encourage investment in energy saving techniques and, in particular, to speed up the marketing of new energy-saving equipment. Projects with a longer pay-back period or a high risk are generally given priority assistance. Notable programs of this kind are the financial and fiscal incentives which are given in Denmark, the Netherlands, and Sweden in order to promote energy-saving investment in industry;
- **reporting and auditing schemes,** often in combination with mandatory or voluntary target setting. Information from reporting and auditing schemes is also used to advise the various sectors of industry and to help governments formulate an energy-related strategy. For instance, mandatory reporting of energy consumption figures or compulsory energy audits are used in the United States and Spain. Voluntary systems exist, for example, in the United Kingdom's industrial Energy Thrift and Audit Scheme;
- **information activities,** including advisory services, in particular to small- and medium-sized industries. They are most effective when they are developed and implemented in close cooperation with industry. A notable example of this kind of program—among others—is the Canadian National Energy Business Program which provides computer-equipped buses to carry out energy audits and give on-site energy conservation advice. Canada has agreed to a close cooperation with the European Community in order to establish similar advice systems in Europe.

With respect to longer term RD&D programs, a recent report prepared for the Battelle Pacific Northwest Laboratories, which compared U.S. industrial energy conservation RD&D programs with those in West Germany, France, England, Sweden, and Japan, concluded that:

> The U.S. Government will probably spend more, in absolute terms, on industrial energy conservation RD&D in 1981 than any one of the four European countries considered.
>
> At the same time, the U.S. Government will spend less than any one of the four European countries per unit of industrial activity. For example, the expenditure of Swedish Government funds per unit of industrial activity is 22 times the U.S. expenditure.[26]

These findings and others in the Battelle study are supported by a report prepared for DOE by DHR, Inc.[27] The Battelle and DHR studies also point out that foreign RD&D is often cost-shared with industry to ensure the earliest possible commercialization and that project funding is seldom awarded on a competitive basis. In addition, foreign governments place greater emphasis than does the U.S. Government on developing technologies for export and in encouraging conservation in industries that must compete in international markets.

## Implications for the United States

An important conclusion to be drawn from comparing U.S. industrial energy use with that in other developed nations is that considerable latitude exists for making U.S. industry more energy efficient, but not to the extent that a simple comparison of energy/GDP ratios would suggest. The United States could clearly benefit from foreign conservation research programs and could learn from foreign energy-using practices, but it would be incorrect to assume that foreign experience provides an easy path to decreased U.S. energy use.

In addition, when historical energy cost differences are taken into account, higher U.S. energy intensities generally do not imply economically inefficient or wasteful practices by U.S. industry. Rather, they indicate rational responses to socially dictated energy price signals. Foreign experience provides considerable evidence that energy use is responsive to energy prices, at least over the long run. Thus, an increase in price may have the effect of reducing energy use, but not necessarily on a short time scale. It is this delayed impact of higher energy prices that has led almost all IEA countries to introduce complementary conservation measures.

[26] "Government-Sponsored Industrial Energy Conservation Research, Development, and Demonstration: A Review of Programs in the Federal Republic of Germany, France, United Kingdom, Sweden, and Japan," Hagler, Bailly, & CO., Aug. 6, 1981 (Battelle contract No. B-B41 54-A-H),

[27] *Conservation and Solar Energy R&D Expenditures,. An International Comparison,* DH R, Inc., Nov. 9, 1981 (DOE contract No. DE-AC01-81 CE1OO97).