Energy Use in the Recent Past and in the Future

Using the framework established in part III, part IV analyzes the recent increase in energy use registered from 1985 to 1988 and speculates about likely changes in energy use from 1988 to 2000.

OVERVIEW

The trend of constant energy use established from 1972 to 1985 was broken between 1985 and 1988 when energy use increased by 8 percent (6 quadrillion British thermal units (Btu) or quads.) Although the energy intensity of the economy continued to decline nom 1986 to 1988, it did so at a meager-O.2 annual rate as opposed to the –2.4 percent decline achieved from 1972 to 1985. The lack of detailed data preclude answering the question of what factors caused this increase, but it appears that an increase in the level of spending coupled with a shift in the mix of consumption towards more energy-intensive products contributed to the increase:

- Of the 10 major sectors of the economy, manufacturing increased its share of total shipments the most from 1985 to 1988, growing from 32.9 percent of all shipments to 33.8. This increase in the economy's share of gross output halted a downward trend that had prevailed since 1972.

This shift in output is reflective of a shift in the mix of spending:

- Federal Governrnent spending took a dramatic change as nondefense purchases fell by 16 percent over the 3-year period and defense purchases grew by 10 percent.
- The export sector experienced the fastest rate of growth of any sector during this period, increasing its share of Gross National Product (GNP) from 10 to 13 percent. Contributing to this surge were energy-intensive manufacturing products like aluminum where exports grew by 44 percent and steel mill products where exports increased by 121 percent horn 1985 to 1988.
- Household spending shifted away from non-**durable to durable goods like furniture and home electronics.**

Although the level and mix of consumption changed between 1985 and 1988 in such a way that energy use increased, reversing the trend set in the 1972-85 period, it does not appear that the energy efficiency of the production processes used to make these products declined over the period:

- Although the economy was experiencing rapid growth that could theoretically have led to inefficiencies as plant capacity was stretched thin, the level of capacity utilization from 1985 to 1988 was lower than that achieved from 1978 to 1980-a period marked by industrial energy-efflciency gains.
- The annual rate of investment in new plant and equipment from 1985 to 1988 was 7 percent, 2 percentage points higher than the 1972-85 annual investment rate. It is likely that these new investments improved energy efficiency.
- The cost of energy did decline significantly horn 1985 to 1988, providing an incentive to ease-up on pursuing energy efficiencies in production processes. But energy efficiencies have been sustained in other periods of falling prices such as horn 1958 to 1971 and 1982 to 1985—although the magnitude of the decline was not as large as that between 1985 and 1988.[82] Nevertheless, low energy prices do not preclude new investments in production process that are being adopted for reasons other that energy efficiency (e.g., higher product quality, increased production flexibility, or lower labor costs) but have the unintended benefit of reducing energy use.[83]

It appears that increases in the level of spending and changes in the mix of what was being bought from 1985 to 1988 caused a realignment of industrial output towards relatively energy-intensive industries, in turn causing an increase in energy use.

Predictions about how energy use and the economy are likely to change in the future are based on a model developed by the U.S. Department of Labor's Bureau of Labor Statistics. The "moderate-growth' ' scenario of this model has the GNP growing at a slower rate in the next 12 years than what occurred in the past 12. Thus, on the basis of sheer growth alone, the increase in energy use should be less in the future than that experienced between 1976 and 1988.

In terms of energy use associated with changes in the composition of output, i.e., structural change, the picture is mixed. The manufacturing sector is predicted to benefit horn increases in exports, while being hurt by decreases in defense spending." All told, manufacturing's share of output is predicted to increase, but much of the growth is in "high-tech" products that have relatively low energy intensities. When viewed across all sectors, changes in energy use associated with changes in the structure of the economy, do not appear to be significant.

The future impact of technology on energy use is even more speculative. Nevertheless, a wide array of energy-saving technologies are already in the market and hold out the potential for significant gains in efficiency. The critical unknowns of the future are less of technical potentials than the willingness to implement the technology.

CHANGES IN ENERGY USE FROM 1985 TO 1988

The 13-year trend of steady decreases in the number of Btu consumed per dollar of Gross Domestic Product (GDP) produced (figure 1) was broken between 1985 to 1988 as energy use increased by 8 percent (6.1 quads) in 3 years.[85] Over half of this increase was in petroleum; a fifth was in the form of coal.[8G] The increase was distributed across all three of the main sectors that the Department of Energy allocates energy use to:

- **residentia1/comrnercial was responsible** for 37 percent of the increase,
- industrial uses contributed 32 percent of the increase, and
- transportation provided 30 percent.[87]

Even though an increase of 6 quads in 3 years is a significant departure horn the flat level of energy use established between 1972 and 1985, the intensity (energy used per dollar of GDP) continued to fall because of the fast pace of real GDP growth (11 percent increase from 1985 to 1988).[88] Nevertheless, the pace of the decline in energy intensity has fallen from -2.4 percent per year horn 1972 to 1985 to-O.8 percent per year from 1985 to 1988.[89] From 1986 to 1988, the decline in energy intensity almost came to a halt, falling at 0.2 percent per year. Why has the rate of decline in energy intensity leveled off after 13 years of steady decreases? Has the rate of energy-efficiency improvements declined? Or has the structure of the economy shifted towards a more energy-intensive mix of industries?

Detailed data, in particular an up-to-date input-output table and industry-specific energy use data, are unavailable, precluding an analysis like that conducted in part III. Nevertheless, some hints as to why energy use increased can be obtained from the more limited data that are available.[w] The analytical framework established in part III suggests four possible factors that could have contributed to the increase:

- growth in the overall level of spending;
- a changing mix of spending towards energy-intensive products;
- changes in the nonenergy portion of the production recipe, requiring more energy; and/or
- changes in the energy portion of the production recipe, that have induced inefficiencies in the use of energy.

Changes in the mix of spending and in the nonenergy portion of the production recipe are collectively labeled structural changes, while changes in energy use due to changes in the energy portion of the production recipe are referred to as changes in technology or energy efficiency.

Growth

The 1985-88 period was a time of strong economic growth: real GDP grew at an annual average rate of 3.7 percent, v. 2.5 percent for the 1972-85 period.[9]1 As shown in part III, sheer growth or an increased level of spending, holding all other changes constant, does increase the use of energy. Finding a period in the past to act as a proxy for 1985 to 1988 is difficult because of the business cycles that affect growth. The 1982-85 period is probably the best proxy for the growth that occurred from 1985 to 1988, because it is the most up-to-date and the fact that both are periods of steady, uninterrupted economic growth. For every $100 billion increase in GDP from 1982 to 1985, energy use due to just growth would have grown by 2.16 quads. Thus, growth from 1982 to 1985 would have caused energy use to increase by 9.8 quads. Applying the 1982 to 1985 formula to the 1985-88 GDP growth, energy use would increase by 8.8 quads, over 40 percent more than the overall increase of 6.1 quads reported by the Department of Energy.[fi] The difference between what was actually observed from 1985 to 1988 and what would have happened if all other factors except growth in the level of spending were kept constant is very small. From 1982 to 1985, changes in the mix of spending (-4.6 quads) and changes in the energy portion of the production recipe or the energy efficiency of industry (-4.0 quads) reduced the increase due to sheer growth by 8.6 quads, resulting in a net, overall increase of only 2.7 quads, less than half of what occurred between 1985 and 1988.

Thus, all of the increase in energy use horn 1985 to 1988 can be attributed to growth in the overall level of spending or GDP, holding all other factors constant. The questions that remain are why were the factors that usually limit this increase due to growth-shifts in the mix of spending, energy savings due to changes in the nonenergy portion of the production recipe, and improvements in energy efficiency of industry-of a smaller size than usual?

Shifts in the Mix of Spending

A shift in the mix of spending would occur if a product's share of growth between 1985 and 1988 was different than the share of spending it represented in 1985. This section looks at how spending on various products changed from 1985 to 1988 relative to the share of consumption that those products held in 1985. This is done for each of the four main areas of spending: households, government, business investment, and international trade. As shown in table 9, a shift in the mix of products purchased, such as horn services to manufactured goods, would cause an increase in energy use.

Households[92]

The shift in the mix of household purchases (personal consumer expenditures) that occurred between 1985 and 1988, tilted spending towards durable goods as opposed to nondurable products. Although durable goods, such as furniture and home electronics, only represented 15 percent of all household consumption in 1985, they were responsible for 24 percent of the increase in household spending from 1985 and 1988. This disproportionate growth of durables came at the expense of nondurable goods such as clothing and food. Nondurable spending represented only 23 percent of the growth, below their 1985 share of 36 percent.

Energy products (which are classified as nondurable) had a mixed experience. Gasoline and oil's share of household purchases declined during this time period,[93] but purchases of fuel oil and coal increased.~ The other major product category within the household sector, services, slightly increased its share from 1985 to 1988 by generating 53 percent of the increase in household spending from a 1985 base of 49 percent.

All in all, products purchased by the household sector seem to have leaned towards a mix that is more energy-intensive: durable goods increased their share over nondurables.[95]

Government[9G]

Data limitations restrict the analysis of the changing mix of government expenditures to the Federal Government, where the mix underwent a radical realignment from nondefense purchases to defense purchases.[97] In real terms, nondefense purchases declined by 16.2 percent from 1985 to 1988, while defense purchases increased by 10.2 percent.[98] The disproportionate growth occurring within defense has been in durable goods (aircraft, missiles, tanks, etc.) which have been responsible for 51 percent of the 1985 to 1988 growth in defense expenditures horn a 1985 share of 30 percent.[w] Thus, government spending at the Federal level has undergone a shift horn nondefense to defense purchases, which are about 1.5 times as energy-intensive.l[m]

International Trade

Of all the sources of demand that make up the GNP, the one that showed the most pronounced disproportionate growth during this period was exports. Although net trade was still in deficit in 1985, exports were responsible for 30 percent of the real, gross 101 increase in GNP between 1985 and 1988, even though exports' share of GNP in 1985 were only 10 percent. Between 1985 and 1988, exports grew by 44 percent while imports increased by only 28 percent. This gain in exports is probably attributable to the sharp devaluation of the dollar that occurred after 1985, making U.S. exports more

[xxix]Calculation: 1982 to 1985 GNP grew by $452.7B, energy use due to growth increased by 9.78 quads, thus quads/GNP = 0.0216. Applied to a 1985 to 1988 GNP increase of $405.7B this results in energy use increasing due to growth of 8.76 quads.

[xxx]Interactive effects resulted in an increase in energy use of 1.6 quads.

attractive overseas.[102] For example, exports of steel mill products increased by 121 percent from 1985 to 1988, while imports of steel mill products decreased by 14 percent.[103] Aluminum also rebounded with exports increasing by 44 percent and imports falling by 5 percent.[104] Over one-half of the increase in overall exports came from capital goods (e.g., machine tools and computers) whose 1985 share was 37 percent.[105] The other leading category of increase was in consumer durables, which generated 11 percent of the growth from a 1985 base of 5 percent. Aside from imports, exports are the most energy-intensive component of demand because exports are largely composed of semifinished intermediate goods and manufactured products that have a high energy content.[106]

In conclusion, it appears that every category of spending either stayed constant or experienced a shift in the mix of spending towards products that are relatively energy-intensive. In particular, exports and defense purchases surged and are undoubtedly part of the reason why energy use increased between 1985 and 1988.

Shifts in Output

***If* the mix** of spending became more energy-intensive, the output horn energy-intensive sectors should also be disproportionately large. Figure 15 illustrates the fact that a slight shift in the composition of output towards energy-intensive industries could have a pronounced effect on energy use. Two data sources, the Federal Reserve Board's Industrial Production Index[107] and the Bureau of Labor Statistics (BLS) Output and Employment Database[108] indicate that a shift in the composition of output towards these energy-intensive sectors occurred between 1985 and 1988.[109]

The Industrial Production Index (IPI) grew by 10.6 percent from 1985 to 1988. Of the three major sectors covered by this index, manufacturing grew by 13.2 percent, mining declined by 5 percent, and utilities grew by 1.8 percent. Within manufacturing the largest percent gains in the index from 1985 to 1988 occurred in lumber (21.5 percent), printing and publishing (19.6 percent), chemicals (19.6 percent), rubber and plastic products (18.6 percent), nonelectrical machinery (which includes computers) (17.8 percent), and paper and paper products (17.4 percent). Three of these six industries produce products that are among the top 11 most energy-intensive (table 9).

The BLS database has shipment (gross output) data on every sector in the economy. Of the 10 major (one digit SIC) sectors, manufacturing increased its share of total shipments the most from 1985 to 1988, growing from 32.9 percent of all shipments to 33.8 percent. The service sector was second, growing from 13.8 percent to 14.2. The 0.9 percent gain in share by manufacturing sounds small, but translates into a $50 billion increase in real shipments over the 3-year period.* This gain in share breaks a trend where manufacturing fell from a 35.8-percent share of output in 1972 to 32.9 in 1985.

Within manufacturing, the three industries experiencing the largest gain in share of manufacturing's total output were machinery, except electrical (which includes the computer industry) whose share grew by 1.4 points, chemicals (0.5 point gain), and primary metals (0.3 gain). Chemicals, primary metals, and to a lesser extent machinery are all relatively energy-intensive industries.

When the increase in output achieved by the manufacturing sector between 1985 and 1988 is multiplied by the 1985 energy intensities shown in table 9, it reveals that just the growth in manufacturing output, holding the energy efficiency of the products constant at their 1985 level, could have caused energy use to increase by 7.7 quad. The big three contributors to this increase were the chemical industry (2.2 quads), primary metals (1.2 quads) and machinery (except electrical (0.8 quad)). A significant portion (90 percent) of this increase is due to sheer growth in the level of output. The change in output mix from 1985 to 1988 caused energy use in the manufacturing sector to increase by 0.77 quad. Although small, the fact that this change in mix led to a net gain in energy use is contrary to the trend established between 1972-85.

These preliminary findings, based on output data, support the idea that a shift in spending (final demand) did occur that caused energy use to increase. Instead of offsetting the increase in energy use due to arise in the level of spending, the mix of spending changed between 1985 and 1988 in such a way that energy use increased-reversing the trend set in the 1972-85 period. Thus it appears that the

***Based in constant 1982 dollars, the total value of gross output for the whole economy in 1988 was $7.3 trillion.**

industrial structure of the economy shifted into a more energy-intensive configuration.

Changes in Energy Efficiency

The other factor that has traditionally acted as a brake on increases in energy use due to growth has been energy savings associated with changes in the way products are made. From 1972 to 1985, nearly four-ftiths of the energy savings attributed to changes in the process of production (the production recipe) were due to changes in the way energy was used as an input.

Given that energy-efficiency improvements were the dominant factor behind the leveling of energy use between 1972 and 1985, could energy-efficiency gains have stopped or even reversed themselves between 1985 and 1988? Evidence indicating how energy efficiency has changed is very limited. In theory, some inefficiencies would be expected as the economy continues to expand and plant utilization begins to hit capacity constraints. For example, as demand for steel continues to rise, moth-balled, old facilities using outmoded technology, like open-hearth furnaces, might be brought back online, causing the energy efficiency of steel production to dip.[110]

At least for the steel industry this has not been the case. The percentage of steel made from relatively inefficient processes, such as open-hearth or blast furnace methods, declined between 1985 and 1988, with the most energy-efficient mode, electric arc, gaining.[111] More generally, the Federal Reserve **Board reports that capacity utilization in manufacturing did increase horn 80 to 83 percent horn 1985 to 1988[112] and that the bulk of this jump occurred in the more energy-intensive primary processing portion of manufacturing** where the capacity utilization rate jumped from 81 to 87 percent.[113] Nevertheless, these capacity utilization levels are below the rates set from 1978 to 1980 when manufacturing hit 86.5 percent of capacity and primary processing climbed to 89.1.[114] Even at these high levels set between 1978 and 1980, efficiency gains were still achieved.[115] It is thus unlikely that the 1985-88 levels of capacity utilization led to significant inefficiencies in energy use.[116]

In fact, this notion that businesses might reactivate old, inefficient modes of production might need updating to take into account the 1982 recession, which led some manufacturers, especially those in the "smokestack" industries, to permanently retire their oldest facilities or transfer operations to offshore sites. Thus, in some cases, the old capacity no longer exists. For example, Pittsburgh was once thought of as the U.S. capital of steel production, but today many of the old U.S. Steel facilities have been torn down and the local economy has shifted towards financial services. U.S. Steel has diversified into retail, transportation, and oil industries.[117]

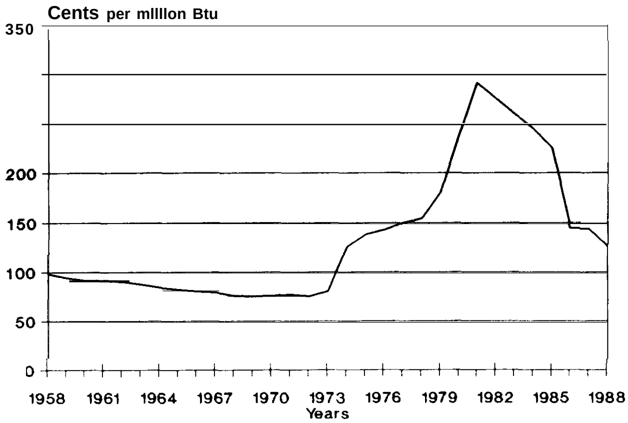
Coupled with this is the fact that investment in new equipment by businesses usually results in energy-efficiency gains as old equipment is replaced by new.[118] The investment rate by businesses during 1972 to 1985—a period of energy-efficiency gains by business-was an annual rate of 4.7 percent, significantly below the 1985 to 1988 rate of 6.9 percent.[119] It is unlikely that these new investments hindered energy efficiency, rather, they are likely to have improved efficiency.

Lastly, the real price of energy dropped from 1985 to 1988, reducing the incentive for making energy-efficiency improvements (figure 18). The price for crude oil & gas, for example, fell from $27 per barrel (current dollars) in 1985 to $14 in 1988.[120] But falling energy prices do not necessarily result in declines in energy-efficiency gains due to changes in the production recipe.[121] Figure 13 shows that savings in energy due to the production recipe were achieved from 1982 to 1985, another period of declining energy prices.[122] Likewise, fuel-efficiency improvements were made between 1958 and 1971, another period of low and falling fuel prices-albeit, not as steep a drop as what occurred between 1985 and 1988.[123] Energy efficiency gains are frequently associated with modernization efforts undertaken to achieve objectives other than energy savings such as improving quality, boosting yields, or increasing the flexibility of production.[124]

Summary

Although a conclusive answer cannot be reached, it appears from the data available that the rise in energy use from 1985 to 1988 was largely due to strong growth in the overall size of the economy and a shift in economic activity towards more energy intensive industries. No evidence was found that would indicate that businesses' energy efficiencies have declined during this period. Rather, it appears that structural shifts toward energy-intensive production could not be countered by energy-efficiency

Figure 18-Composite Fossil Fuel Prices (1982 dollars)



The real composite price of energy was relatively flat from 1958 to 1973. Between 1973 and 1981, the price more than tripled and then began to decline, failing sharply between 1985 and 1988.

NOTE: All fuel prices taken as close as possible to the point of production. Deflated using implicit GNP price deflators.

SOURCE: U.S. Department of Energy, Energy Information Agency, *Annual Energy Review, 1988* (DOE/EIA-0384(88)), May 1989, table 27, p. 65.

improvements, leading to a net increase in energy use. Some of this structural shift could be due to a leveling of household energy efficiency, which would affect the mix of household purchases.[125] It is important to note that changes in economic structure are not as permanent as the word 'structure' would suggest. Trends in both industrial structure and energy use can be reversed in a relatively short time. This increase in energy use due to changes in the structure of the economy could be hiding decreases in energy use due to efficiency gains that continue to be made.

In any event, a 6-quad, 8-percent increase in 3 years-reaching an all-time peak in energy use, which breaks a precedent established over 13 years of very little or no growth in energy use, is surprising and necessitates a more thorough analysis than that provided here. A prerequisite for that analysis is more timely and detailed data.[126]

SPECULATION ABOUT ENERGY USE IN THE FUTURE

This up-tick in energy use from 1985 to 1988 generates concern about whether we are approaching limits to the energy-efficiency improvements we can expect in the fiture.[127] Speculation about future energy use is fraught with difficulties and caveats. Factors that can be incorporated into a computer model tend to be insignificant in comparison to events that are nearly impossible to predict, such as the invention of the microchip or the Iranian Revolution. Attempts at specific forecasts made in the mid- 1970s accurately predicted that the energy intensity of the U.S. economy would decline, but underestimated the rate of the decline, leading to predictions that were 42 percent above actual use.[128]

For the purposes of this report, broad future trends, which lend a sensitivity to what is likely v. what is unlikely, are more appropriate than specific predictions. The discussion is broken into two sections, economic growth and technology, that roughly correspond to the framework of structure and energy efficiency used throughout this report.

Economic Growth

Economic growth is determined by a myriad of factors, including demographics, government spending, monetary policy, trade policy, income distribution, productivity rates, and savings rates.[129] Accounting for all these factors simultaneously, even in a broad framework, is beyond the scope of this report. As a result, this discussion relies on the findings of work done by BLS in their estimate of employment for the year 2000.[130] Their projections are based on a number of inputs, including an econometric model prepared by Data Resources, Inc.; demographic projections estimated by the Bureau of Census; and energy use projected by the U.S. Department of Energy.[131]

The BLS projections include three scenarios: high-, moderate-, and low-growth. Table 10 shows the 1988 to 2000 GNP growth rates and unemployment rates for each of the scenarios as well as corresponding figures for the previous 12-year period, 1976-88. The moderate-growth scenario is arbitrarily selected as a vehicle for setting parameters of what is likely and unlikely to happen. The growth rate of GNP under the moderate-growth scenario is less than that achieved between 1977 and 1988, largely because of a projected slowing of the growth in the size of the labor force and an expectation that the Federal budget and foreign trade deficits will be reduced.[132]

The slowdown in growth in the next 12 years in comparison to the last 12 means that expenditures from the household and government sectors will decline relative to growth in GNP, while exports will increase at a rate that exceeds GNP growth.[133] The

Table 1O--BLS Projections of GNP Growth Rates and Unemployment Rates Under Scenarios of Low-, Moderate-, and High-Economic Growth

Real GNP annual growth rate				
		1988-2000 Economic growth		
1976-1988		Low	Moderate	High
2.9		1.5	2.3	3.2
Civilian unemployment rate				
		2000 Economic growth		
1976	1988	Low	Moderate	High
7.7	5.5	7.0	5.5	4.0

SOURCE: Norman C. Saunders, "The Aggregate Structure of the Economy," *Monthly Labor Review*, November 1989, p. 14.

slowdown in the household sector is attributed to a slower rate of population growth and household formations. In particular, expenditures on household furnishings and motor vehicles are predicted to decline.l[w] The desire to reduce the Federal budget deficit is predicted to cause a reduction in the level of military expenditures and cause moderation in nondefense spending, leading to a balanced Federal budget late in the century. Assuming that the value of the dollar remains low, BLS projects that imports will decline as exports, particularly manufacturing machinery, increase due to strong economic growth overseas.[135] In such a scenario, the trade deficit comes into balance in the mid-1990s.[136]

This moderate-growth scenario translates into healthy output increases in durable manufacturing, wholesale trade, and services (health, business services, and child care) sectors (table 11).[137] In terms of energy use, 4 of the top 15 most energy-intensive industries are predicted to have above average growth from 1988 to 2000.[138] The largest gains occur in relatively high value-added but less energy-intensive manufactured products like computers, semiconductors, and optical products.[139] The fraction of output devoted to services continues to grow under this scenario with especially strong growth in computer and data processing, nursing facilities, outpatient facilities, child care, and residential care (senior citizen complexes)-industries that are relatively low in energy intensity.

BLS predictions suggest that economic growth in the next decade will be lower than it was in the recent past. Thus, on the basis of sheer growth alone, the increase in energy use should be less in the future than it was between 1976 and 1988. In terms of energy use associated with changes in the composition of output-structural change-the picture is mixed. The manufacturing sector is predicted to benefit from increases in exports, while being hurt

Table 11—BLS Projections of Output[a] by Major Industry Division Under a Scenario of Moderate Economic Growth

Real GNP annual growth rate	Percent distribution 1976	1988	2000 Moderate	Annual rate of change 1976-1988	1988-2000 Moderate
Total	100.0	100.0	100.0	2.7	2.3
Goods-producing	46.4	43.5	43.0	2.1	2.2
Mining	4.2	3.0	2.5	-0.1	0.6
Construction	6.7	6.6	6.5	2.6	
Manufacturing	35.5	33.8	34.0	2.2	
Durable	17.8	17.7	18.9	2.6	2.9
Nondurable	17.8	16.2	15.1	1.9	1.7
Service producing	50.3	53.9	54.5	3.3	2.4
Transportation and utilities	8.8	8.3	8.4	2.2	2.4
Wholesale trade	5.0	5.7	6.1	3.9	2.9
Retail trade	6.8	7.6	7.5	3.6	2.1
Finance, insurance, and real estate	11.1	11.8	11.9	3.2	2.3
Services	11.5	14.2	15.1	4.5	2.8
Government	7.1	6.3	5.5	1.6	1.0
Agriculture	3.1	2.5	2.4	0.7	1.9
Private households	0.4	0.3	0.2	0.7	0.8

aGross duplicative output.

NOTE: Totals may not add due to rounding.

SOURCE: Valerie A. Personick, "Industry Output and Employment: A SlowerTrend for the Nineties," Month/y Labor Review, November 1989, p. 28.

by decreases in defense spending. On net, manufacturing's share of output is predicted to increase, but much of the growth is in "high-tech" products that have relatively low energy intensities.[140] When viewed across all sectors, changes in energy use associated with changes in the structure of the economy do not appear to be significant.

Technology

By causing the mix of what people bought to change (spending mix) and by changing the way businesses produced output (production recipe), technology was a major factor in offsetting the increase in energy use due to sheer growth in the economy from 1972 to 1985. Detailed estimates about the technical potential of future energy-efficiency gains is beyond the scope of this analysis.[141] Nevertheless, a wide array of energy-saving technologies exist that could significantly improve U.S. energy efficiency.[142] Table 12 provides an incomplete listing of some of the technologies that are already commercially available, but have yet to be fully implemented. The intent is to provide a feel for the range and diversity of energy saving technologies, not a comprehensive list of all available technologies or a projection of potential gains or losses.

CONCLUSION

It is easy to be dazzled by the potential energy savings offered by technology, but realizing this potential is fraught with a great number of uncertainties.[143] What will it cost? How will it change my lifestyle? How will unknowns, such as geopolitical changes, affect the adoption of a particular technology? How will energy savings mesh with other public goals? Ultimately, energy use will be dictated by the answers to these questions.

Structural changes that result in less use of energy and the continued improvement in energy efficiency are likely to continue in the future. A driving force behind these two factors will be the continued development and diffusion of information technologies. Just as electricity generated tremendous energy efficiencies as it freed factory design from the restrictions associated with steam and water power, information technologies hold out the promise for another revolution in the reamer of production.[144] These information technologies will place a premium on exploiting flexibility and the ability to monitor and control production to exact specifications, characteristics that are inherently energy-conserving.

These energy savings associated with energy-eflciency gains should be bolstered by structural changes in the economy. The creation of a basic infrastructure (railroads, factories, highways) that requires inputs horn energy-intensive industries, such as steel and cement has been completed, although the repair and maintenance of these systems will require significant additional resources in the future.[145] Material-intensive consumer products such as stoves, washing machines, refrigerators, etc. have begun to hit saturation points.[146] The sectors of the economy that appear likely to dominate in the future-information processing, software production, biotechnology, aerospace, communications, advanced materials-have strong "energy-saving and-avoiding biases. "147 Even in energy-intensive sectors such as manufacturing, success in the future will hinge on the service component of a product—timeliness, quality, tailoring to the individual customer—not the energy-intensive material portion of the product.

In this sense, speculation about future energy use has to include consideration not only of how technology will affect energy consumption, but also how changes in the industrial makeup of the economy will affect the demand for energy. As can be seen from the 1972-85 and 1985-88 periods, these factors can change relatively quickly.

The future holds a unique opportunity for achieving economic growth without incurring the costs associated with increased energy use. Achieving this future in not a function of what the United States can or can not do. History illustrates that economic growth can be achieved with little or no increase in energy use. Rather, the future is dependent on what Americans choose to do as consumers, business people, and voters.

Table 12—Commercially Available Technologies That Improve Energy Efficiency

Residential/Commercial

- Switching from standard fluorescent ballasts to more efficient solid-state electromagnetic ballasts decrease energy use by 20 to 25 percent, adding an optical reflector to fluorescent lamps increases useful light output by 75 to 100 percent, cutting energy use by 30 to 50 percent.[1]
- It is possible to develop windows with thermal insulation equivalent to 3 inches of fiberglass.[2]
- The efficiency of most home appliances (refrigerators, freezers, central air-conditioners, electric water heaters) can be nearly doubled by using technology already on the market.[3]
- Demonstration homes in Minnesota that use new insulation techniques use 68 percent less heat than the average U.S. home.[4]
- Installing Variable Air Volume (VAV) systems that react to changes in heating and cooling needs by adjusting the amount of air-conditioning can generate savings from 25 to 80 percent over standard systems.[5]
- Information technologies, such as Energy Management Systems (EMS), can be applied to optimize the heating and cooling needs of a building. These systems range from simple timers to sophisticated microprocessor-based systems. Computerized EMS typically provides a 10 to 20 percent savings.[6]

Automobiles[7]

Available new technology	Prevailing technology	(Percent gain) fuel savings
4-valves/cylinder	2-valves/cylinder	10
Turbocharging	standard carburetor	5-10
Fuel injection	standard carburetor	6
Continuously variable transmission	3-speed automatic	10
Overdrive	3-speed automatic	7
Aerodynamic design	15% reduction in drag	3

Industry

- Electrically driven freeze process is estimated to use one-eighth as much energy as the fuel-based evaporators.[8]
- Recovery of waste heat in the chemical industry has reduced energy use per pound of product by 43 percent since 1974, and the potential for further cuts of 32 to 48 percent exist.[9]
- The use of ultraviolet radiation to dry paint and cure plastic resins, reduces curing time from 20 minutes to 1/15th of a second.[10]
- Use of continuous casting technology, as opposed to ingot casting, in the steel industry reduces energy consumption by half and increases product yield from 80 to 95 percent.[11]
- Adjustable-speed drives already in application get energy savings of 20 to 25 percent in compressors, 30 to 35 percent in blowers and fans, and 20 to 25 percent in pumps.[12] It is estimated that on average, adjustable-speed motors cut electricity requirements by one-fifth.[13]

[1]H.S. Geller, "Commercial Building Equipment Efficiency: A State-of-the-Art Review," contractor report prepared for the Office of Technology Assessment, May 1988, p. 12; Electric Power Research Institute, "Lighting the Commercial World," *EPRI Journal*, December 1989, pp. 12-13; and J.H. Gibbons, P.D. Blair, and H.L. Gwin, "Strategies for Energy Use," *Scientific American*, September 1989, p. 140.
[2]S. Selkowitz, "Window Performance and Building Energy Use: Some Technical Options for Increasing Energy Efficiency," *Energy Source: Conservation and Renewables*, D. Hafemeister, H. Kelly, and B. Levi (eds.) (New York, NY: American Institute of Physics, 1985).
[3]Howard Geller, "Residential Equipment Efficiency: A State-of-the-Art Review," contractor report prepared for the Office of Technology Assessment, December 1987, p. 3.
[4]J.H. Gibbons, P.D. Blair, and H.L. Gwin, "Strategies for Energy Use," *Scientific American*, May 1988, p. 141.
[5]H.S. Geller, "Commercial Building Equipment Efficiency: A State-of-the-Art Review," contractor report prepared for the Office of Technology Assessment, May 1988, p. 10.
[6]H.S. Geller, "Commercial Building Equipment Efficiency: A State-of-the-Art Review," contractor report prepared for the Office of Technology Assessment, May 1988, p. 8.
[7]K.G. Duleep, Energy and Environmental Analysis, Arlington, VA, "Developments in the Fuel Economy of Light-Duty Highway Vehicles," contractor report prepared for the Office of Technology Assessment, August 1988.
[8]M. Ross, "Improving the Energy Efficiency of Electricity Use in Manufacturing," *Science*, vol. 244, Apr. 21, 1989, p. 244.
[9]U.S. Department of Energy, Oak Ridge National Laboratory, *Energy R&D: What Could Make a Difference?* vol. 2, part 1, May 1989, p. 71.
[10]C.A. Berg, "The Use of Electric Power and the Growth of Productivity: One Engineer's View," draft, Northeastern University, Boston, MA, p. 33.
[11]U.S. Department of Energy, Oak Ridge National Laboratory, *Energy R&D: What Could Make a Difference?* vol. 2, part 1, May 1989, p. 86.
[12]S.F. Baldwin, "The Materials Revolution and Energy-Efficient Electrical Drive Systems," *Annual Review of Energy*, vol. 13, 1988, p. 87.
[13]A. Kahane and R. Squitieri, "Electricity Use in Manufacturing," *Annual Review of Energy*, vol. 12, 1987, p. 236.

NOTES FOR PART IV

[82]The composite constant dollar price for energy fell by an annual average rate of 1.9 percent between 1958 and 1971, 6.3 percent from 1982 to 1985, and 17.7 percent from 1985 to 1988. U.S. Department of Energy, Energy Information Administration, *Annual Energy Review, 1988* (Washington DC: Energy Information Administration, May 1989), table 27, p. 61.

[83]H.C. Kelly, P.D. Blair, and J.H. Gibbons, "Energy Use and Productivity: Current Trends and Policy Implications," *Annual Review of Energy*, vol. 14, 1989, p. 345; R.C. Marlay, "Trends in Industrial Use of Energy," *Science*, vol. 226, Dec. 14, 1984, p. 1282; and M. Ross, "Improving the Energy Efficiency of Electricity Use in Manufacturing," *Science*, vol. 244, Apr. 21, 1989, p. 316.

[84]Norman C. Sanders, "The Aggregate Structure of the Economy," *Monthly Labor Review*, November 1989.

[85]U.S. Department of Energy, Energy Information Agency, *Monthly Energy Review*, August 1989, table 1.4, p. 7.

[86]Ibid., table 1.4, p. 7.

[87]Ibid., table 2.2, p. 21.

[88]National Income and Product Accounts, op. cit., endnote 4, table 1.8.

[89]*Monthly Energy Review*, August 1989, op. cit., endnote 1, table 1.7, p. 12.

[90]For an analysis of the change that occurred between 1987 and 1988, see H.S. Geller, "U.S. Energy Demand: Back to Robust Growth?" Energy Efficiencies Issues Paper No. 1 (Washington, DC: American Council for an Energy-Efficient Economy, March 1989).

[91]U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts, table 1.2.

[92]The source for this analysis is the National Income and Product Accounts, op. cit., endnote 4, table 2.5.

[93]Although the number of miles driven by passenger cars increased over this time period, the miles obtained per gallon of gas (MPG or fuel-efficiency) also increased resulting in a decline in the average number of gallons consumed per car. *Monthly Energy Review*, August 1989, table 1.10, p. 15.

[94]Possibly because of an increase in the number of housing units. Geller reports that occupied housing units increased by 2.9 percent from 1986 to 1988. See H.S. Geller, "U.S. Energy Demand: Back to Robust Growth?" Energy Efficiencies Issues Paper No. 1 (Washington, DC: American Council for an Energy-Efficient Economy, March 1989), p. 3; and National Income and Product Accounts, op. cit., endnote 4, table 2.5.

[95]Hannon calculated that 1972 personal consumer expenditures on durable products were 7 percent more energy-intensive than nondurables. B. Hannon, "Analysis of the Energy Cost of Economic Activities: 1963 to 2000," *Energy Systems and Policy Journal*, vol. 6, No. 3, 1982, p. 261.

[96]Data for this section come from National Income and Product Accounts, op. cit., endnote 4, tables 1.2 and 3.9.

[97]The National Income and Product Accounts do not have expenditure data for State and local government for 1988 and do not publish any constant dollar figures for State and local expenditures by item.

[98]National Income and Product Accounts, op. cit., endnote 4, table 1.2.

[99]National Income and Product Accounts, op. cit., endnote 4, table 3.10.

[100]Hannon, op. cit., endnote 23, p. 261.

[101]This gross figure excludes the losses in GNP attributed to imports.

[102]The real dollar index of the dollar where 1973:Q1 is 100, fell from 117 in June of 1985 to 90.5 in June of 1988. Federal Reserve Bank of Dallas, RX-101 Real Dollar Index: Monthly, 1976-88.

[103]Measured in net tons. American Iron and Steel Institute, *Annual Statistical Report, 1988*, 1989, tables 14 and 18, pp. 34 and 44.

[104]Measured in millions of pounds. The Aluminum Association, *Aluminum Statistical Review for 1988*, vol. 94, No. 94, 1989, p. 5.

[105]National Income and Product Accounts, op. cit., endnote 4, table 4.3.

[106]U.S. Department of Energy, *Energy's Role in International Trade: Structural Change and Competitiveness*, Office of Policy Planning and Analysis, July 1989, p. 1-8.

[107]1985 data is from the U.S. Department of Commerce, Bureau of Census, *Statistical Abstract of the United States, 1989*, table 1273, p. 730. The 1988 data is from the U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, vol. 69, No. 9, pp. s1-s2.

[108]U.S. Department of Labor, Bureau of Labor Statistics, "Historical Input-Output Time Series Data Base," unpublished, January 1989.

[109]Both of these sources suffer from limitations. The Industrial Production Index covers only manufacturing, mining, and utilities, preventing any analysis of the role the service sector might have played. Both the Industrial Production Index and the BLS database contain gross output or shipments data by industry, not value-added. Shipments data reflect the value of the whole product, which in most cases consist of components made by other businesses, not just the value contributed by the company. Businesses can boost their shipments simply by "out-sourcing" more intermediate parts—in some cases the whole product can be out-sourced. In this respect, shipments data include a lot of double counting since both the supplying firm and the buying firm count the same product as output. The double-counting makes calculating shares of output by industry and a shifting mix of the economy from gross output data problematic. In addition, the BLS 1988 data is of a preliminary nature. Unfortunately, there are no ready alternatives since constant dollar value-added by industry (Gross Product Originating) data—the preferred measure of structural change—also has drawbacks and is currently not available as it undergoes revision by the Bureau of Economic Analysis. See U.S. Congress, Office of Technology Assessment, *Statistical Needs for a Changing U.S. Economy*, OTA-BP-E-58 (Washington, DC: U.S. Government Printing Office, September 1989); and U.S. Department of Commerce, Bureau of Economic Analysis, "Gross Product by Industry: Comments on Recent Criticisms," *Survey of Current Business*, July 1988. See Bernard Gelb, "The Measurement of Output," The Conference Board, *Energy Consumption in Manufacturing* (Cambridge, MA: Ballinger Publishing, 1974), p. 80 for more on output measures.

[110]In some cases, higher levels of operating capacity result in greater energy efficiencies since many uses of energy are fixed inputs that are not strictly proportional to increases in the volume of production. Thus as production increases the energy used per dollar of output falls, resulting in efficiency gains.

[111]American Iron and Steel Institute, *Annual Statistical Report, 1988*, table 1B.

[112]Second quarter of 1988.

[113]U.S. Department of Commerce, *Statistical Abstract of the United States, 1989*, table 1274, p. 730, primary processing includes textiles, lumber, paper and pulp, petroleum, rubber, stone, clay, glass, primary metals, fabricated metals, and a portion of chemicals.

[114]*Federal Reserve Bulletin*, Board of Governors of the Federal Reserve System, Washington, DC, November 1989, table 2.12, p. A48.

[115]G. Boyd, J.F. McDonald, M. Ross, and D.A. Hanson, "Separating the Changing Composition of U.S. Manufacturing Production From Energy Efficiency Improvements: A Divisia Index Approach," *The Energy Journal*, vol. 8, No. 2. 1987, p. 86.

[116]Given that many of the industrial uses of energy are to run "fixed" rather than "variable" modes of production (e.g., motors), it is likely that high utilization rates result in an increase in energy efficiency. See U.S. Department of Energy, *Energy Conservation Trends*, Office of Policy Planning and Analysis, September 1989, p. 11.

[117]Barry Bluestone and Bennett Harrison, *The Deindustrialization of America* (New York, NY: Basic Books, 1982), pp. 6 and 40.

[118]U.S. Department of Energy, *Energy's Role in International Trade: Structural Change and Competitiveness*, Office of Policy Planning and Analysis, July 1989, pp. 2-11.

[119]National Income and Product Accounts, op. cit., endnote 4, table 5.7.

[120]Landed cost of imports. *Monthly Energy Review*, August 1989, table 9.1, p. 91.

[121]U.S. Department of Energy, *Energy Conservation Trends*, Office of Policy Planning and Analysis, September 1989, p. 10; W. Walker, "Information Technology and The Use of Energy," *Energy Supply*, October 1985, p. 461; C.P. Doblin, "Declining Energy Intensity in the U.S. Manufacturing Sector," *The Energy Journal*, vol. 9, No. 2, 1988, p. 117; C.A. Jenne and R.K. Cattell, "Structural Change and Energy Efficiency in Industry," *Energy Economics*, April 1983, p. 120; R.H. Williams, Eric D. Larson, and Marc Ross, "Materials, Affluence, and Industrial Energy Use," *Annual Review of Energy*, 1987, p. 103.

[122]Crude oil declines from $33 to $27 per barrel. Landed cost of imports. *Monthly Energy Review*, August 1989, table 9.1, p. 91.

[123]Marc Ross, "The Potential for Reducing the Energy Intensity and Carbon Dioxide Emissions in U.S. Manufacturing," unpublished draft, 1989, p. 2.

[124]H.C. Kelly, P.D. Blair, and J.H. Gibbons, "Energy Use and Productivity: Current Trends and Policy Implications," *Annual Review of Energy*, vol. 14, 1989, p. 345, Marlay, op. cit., endnote 78, p. 1282; Ross, op. cit., endnote 83, p. 316; and J. Goldemberg, T.B. Johansson, A.K.N. Reddy, and R.H. Williams, *Energy for a Sustainable World* (Washington, DC: World Resources Institute, September 1987), p. 6.

[125]U.S. Department of Energy, *Interim Report: National Energy Strategy*, April 1990, p. 20; and L. Schipper and A. Ketoff, "Energy Efficiency: Did We Reach a Plateau?" mimeo, Mar. 1, 1989.

[126]For a discussion on demand-side energy data, see E. Hirst, Oak Ridge National Laboratory, "Comparison of EIA Data Collections: Electricity Supply and Demand," mimeo, October 1989.

[127]For example, a number of witnesses in public hearings for the National Energy Strategy expressed the concern that substantial further energy efficiency gains in industry "... would likely require major capital investments in new processes yet to be developed." U.S. Department of Energy, *Interim Report: National Energy Strategy, April 1990, p. 33.*

[128]E.A. Hudson, and D.W. Jorgenson, "U.S. Energy Policy and Economic Growth, 1975-2000," *Bell Journal of Economics*, autumn 1974, vol. 5, No. 2, p. 491.

[129]For a more detailed discussion of the factors that affect economic growth and structural change, U.S. Department of Energy (July 1989), op. cit., endnote 9, p. 2-1.

[130]Norman C. Sanders, "The Aggregate Structure of the Economy," *Monthly Labor Review*, November 1989.

[131]Ibid., pp. 13-14.

[132]Ibid., p. 13.

[133]Ibid., p. 17.

[134]Ibid., pp. 17-18.

[135]The decline in purchases of imports and increase in exports is to some extent a reflection of foreign manufacturing firms' operating plants in the United States.

[136]Sanders, op. cit., endnote 130, p. 21.

[137]Valerie A. Personick, "Industry Output and Employment: A Slower Trend for the Nineties," *Monthly Labor Review*, November 1989.

[138]Based on 1985 product energy intensities shown in table 9. The four industries and their intensity ranks are plastic materials (no. 8), air transportation (no. 10), paper and allied products (no. 11), and water and sanitation (no. 14).

[139]Personick, op. cit., endnote 137, p. 35.

[140]Problems with valuing "high-tech" products like computers and semiconductors makes projections of output in these industries imprecise. See Personick, op. cit., endnote 137, pp. 37-38.

[141]See F. Duchin and G. Lange, "Technological Choices and Their Implications for the U.S. Economy, 1963-2000: Report on the Construction and Application of an Engineering/Input-Output Model and Database," Final Report to the National Science Foundation (grant no. ENG-8703347), March 1990 for a more rigorous analysis of technological effects on the economy.

[142]For a more comprehensive discussion of energy technologies, see U.S. Department of Energy, Oak Ridge National Laboratory, *Energy R&D: What Could Make a Difference?* vol. 2, part 1, May 1989; or J. Goldemberg, T.B. Johansson, A.K.N. Reddy, and R.H. Williams, *Energy for a Sustainable World* (Washington, DC: World Resources Institute, September 1987).

[143]For example, recent estimates predict that the most we can expect from superconductors is a 7 percent reduction in 1986 electricity levels. Achieving this reduction is estimated to take 30 to 40 years. Nils-Johan Bergsjo and Lars Gertmar, "Superconductivity and the Efficient Use of Electricity," *Electricity*, T.B. Johansson, B. Bodlund, and R.H. Williams (eds.) (Lund, Sweden: Lund Press, 1989), p. 422; and Walker, op. cit., endnote 2, p. 472.

[144]Baldwin, op. cit., endnote 52, p. 67; and Walker, op. cit., endnote 2, p. 463.

[145]Eric D. Larson, Marc H. Ross, and Robert H. Williams, "Materials, Affluence, and Industrial Energy Use," *Annual Review of Energy*, vol. 12, 1987, pp. 113-114.

[146]Ibid.

[147]Walker, op. cit., endnote 2, p. 463.