Introduction

OVERVIEW

Energy is a fundamental input into our economy, essential for running the country's factories, shipping the Nation's output, and ringing up the sales. Energy is also a final product consumed by itself, responsible for providing many of the comforts of life that people have grown accustomed to: heat in the winter, light at night, cool air in thesummer, and mobility, to name a few. But the consumption of energy has drawbacks as well. Energy use generates pollution and can hurt our balance of trade while making the United States vulnerable to foreign pressures.[i]

Shifts in Energy Use and Gross Domestic Product (GDP)

Given the critical role energy plays in our economy, it is important that we understand how energy use has changed with changes in our economy. Figure 1 gives an overview of this relationship. After World War II, growth in our economy, as reflected by GDP,[ii] and increases in energy, measured in British thermal units (Btu),[iii] appeared to be in lock step. From 1950 to 1971, energy use and GDP both increased at an average annual rate of 3.5 percent. Although deviations from this trend occurred in the mid- 1950s and mid- 1960s, growth in the two factors were highly correlated.[1] Economic growth was assumed to be linked to increases in energy use and public and private investments were made that rested on this assumption.[2]

In the early 1970s, the apparent link between increasing GDP and rising energy use came unraveled. Between 1972 and 1985, 20 million homes were added to the country's housing stock, the fleet of vehicles on America's roadways increased by 50 million, the number of business establishments rose by 1.5 million, and the GDP grew by 39 percent in real terms.[3] But energy use had remained basically flat. Although the average growth rate of GDP was 2.5 percent per year over this period, energy use increased at an annual rate of only 0.3 percent.[4] The energy intensity or units of Btu used to produce a dollar's worth of the economy's output (GDP), which was relatively flat from 1950 to 1971, fell by 2.4 percent per year from 1972 to 1985, resulting in an overall drop in U.S. energy intensity of over a quarter from 1972 to 1985.[5]

This trend of decreasing energy use per dollar of GDP ended in 1986. From 1986 to 1988, the two factors began to grow in parallel again with energy use increasing at a 3.9 percent annual rate and GDP growing at 4.1 percent. The energy intensity of the U.S. economy fell at a meager annual rate of 0.2 percent between 1986 and 1988.

Purpose and Scope

The purpose of this report is to:

- explore how this drop in energy intensity between 1972 and 1985 occurred,
- why it stopped between 1986 and 1988[iv] and
- briefly speculate about what is likely to happen in the future.

The factors underlying this changing relationship between energy use and the economy are important for understanding the role energy plays in the economy, how that role has changed, and how it is likely to evolve in the future.

Tracing how the connection between changes in energy use and changes in the economy has evolved requires identifying specific factors that are critical variables in the process. This report explicitly looks at how changes in the level of overall spending, the mixture of what is being purchased, international trade, and how things are made (technology) affect energy use.

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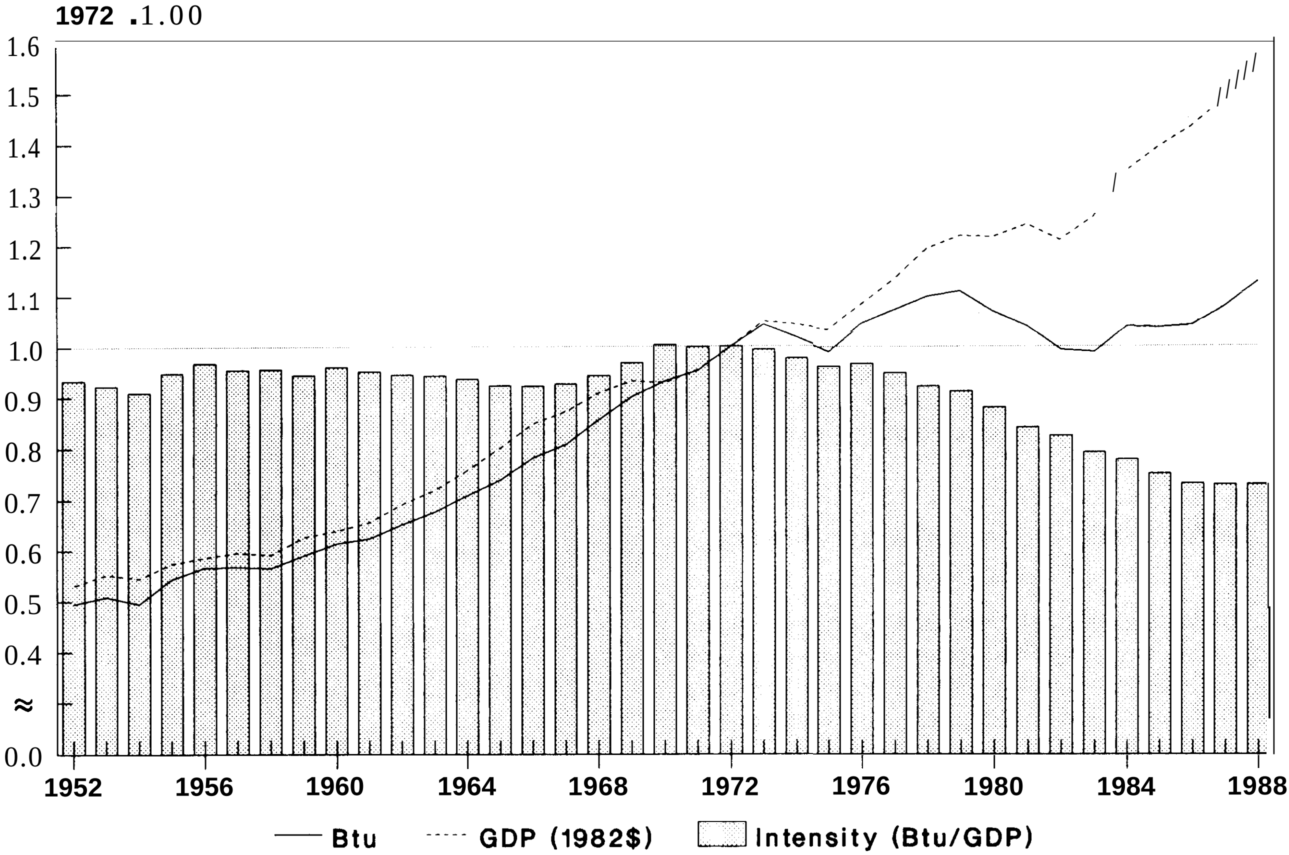
[i] An exception to this statement would be renewable sources of energy which constitute about 4 percent of the total 1988 energy use. U.S. Department of Energy, *Annual Energy Review 1988*, table 3, p. 11.

[ii] GDP is the sum of all output produced in a year that was sold in the formal market (GNP) minus net payments paid to foreigners as returns on their investments in the United States and the return gained by U.S. citizens on their investments overseas. All GDP figures used in this report are in constant 1982 dollars. (See the appendix for more detail.)

[iii] A British thermal unit (Btu) is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. A Btu equals 252 calories.

[iv] Data availability limit the analysis to 1988.

Figure l-index of U.S. Energy Use, GDP, and Energy Intensity



Energy use (Btu) and economic growth (GDP) grew in parallel from 1952 to 1971, causing the energy intensity (Btu/GDP) to be relatively flat. After 1971, GDP continued to grow, but energy use stayed relatively constant, resulting in a decline in the energy intensity until 1988. Due to an increase In energy use after 1985, the energy intensity stayed level from 1988 to 1988.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Acoounts, table 1.2; U.S. Department of Energy, Energy information Agency, *Annual Energy Review 1987* table 4; and the *Monthly Energy Review,* August 19S9, table 1.4.

This separation is important because confusion abounds over how the United States was able to keep the economy growing during the 1970s and 1980s, but hold energy use steady. Some observers attribute the decline in Btu used per dollar of GDP solely to increases in energy efficiency.[6] This is only part of the story. Factors such as changing tastes, incomes, demographics, and international competition led to a shift in the makeup of the economy's output as "smokestack' industries' position declined relative to services and light manufacturing.[7] This change in the structure of the economy also led to less energy used per dollar of output produced. Some of this confusion between declining Btu per dollar of output (energy intensity) and increased energy efficiency is due to semantics and different assumptions. Part II of this report describes in more detail the definitions and analytic structure used in this analysis.

The bulk of the report focuses on the 1972-85 period when energy use stayed flat, but the economy continued to grow (part III). Many other studies have examined the relationship between energy use and the U.S. economy during the 1970s and early 1980s, focusing on the effect of energy efficiency and industrial shifts within the economy on energy use. This report is in general agreement with those studies, but extends the analysis into several new directions.[8]

One of these differences is that most previous research focused exclusively on the industrial sector of the U.S. economy—roughly 30 percent of GDP.[9] This study covers all sectors of the economy.

v Defined as the sum of the agriculture, mining, construction and manufacturing sectors.

Technological advances in information processing (computers, communications, robotics, etc.) are changing the nature of the U.S. economy, making it more complex and interdependent. For example, a dollar spent on food ends up providing only 15 cents to the sector that includes agriculture and 26 cents to manufacturing. Forty cents of the dollar spent on food is retained by services such as transportation and retail trade, an additional 13 cents goes to transactional services like banking, advertising, and law.[10] Information technologies have increased the interdependence of these different sectors, creating networks that link the consumer to the retailer, the retailer to the manufacturer, and the manufacturer to his suppliers.[11] In an economy such as this one, conventional divisions that separate manufacturing from services and the commercial sector from the transportation sector, miss the interaction that occurs between those components.

In a highly developed economy consisting of innumerable interconnections, the role of energy is less likely to be directly identified and is instead more likely to be an indirect factor that was added many steps before in the complex network that connects producer to consumer. For example, to assemble all of the motor vehicles made in 1985 required relatively little **direct** energy, about 0.23 quadrillion Btu (quads), but it required 1.22 quads of **indirect** energy use because the materials used in a car (steel, rubber, glass, plastic) require a lot of energy in their manufacture and fabrication. Thus, most of the energy associated with making a motor vehicle is not at the assembly plant, but was added a few steps before at the steel mill, tire plant, or glass factory. From this perspective, a change in the nonenergy inputs (e.g., material substitution) used to make a product could indirectly affect energy use. This report explicitly separates direct and indirect energy use.

This division between direct and indirect energy use is especially appropriate when the energy associated with international trade is considered. Most calculations presented in this analysis as well as most conventional measures of U.S. energy use, include only direct energy imports-such as barrels of oil or megawatt-hours of electricity. Nevertheless, as production networks continue to extend beyond a country's borders, the inclusion of the indirect energy embodied in the trade of nonenergy products is increasingly important in calculating a country's total energy use. For example, including only the direct energy needed to make a U.S. automobile would miss the energy embodied in a steel axle that was imported from Japan.

Lastly, this analysis goes beyond most previous work by sketching how energy use changes with shifts in the economy. This greater detail adds explanatory power and helps in connecting the findings to public policies. For example, the broad category of structural change is divided into changes emanating from consumers and businesses. Changes due to consumer spending are looked at from three angles: overall level and mix of the products purchased, sources of consumption (e.g., households, government), and type of product being consumed (e.g., manufactured goods v. services). Similarly, shifts in energy use due to changes in the way businesses make their products are broken down by type of product and by changes that either directly or indirectly affect energy use (e.g., material substitution).

The model used for this analysis, like all simulations of reality, is not free of shortcomings. These are outlined in part II. In particular, no attempt was made to explain *why* these changes in the economy or in energy use occurred. Instead, only the question of *how* shifts in the economy affected energy use is explored. As a result, although the industrial structure of the economy and the implementation of technology is undoubtedly affected by changes in tastes, incomes, government regulations, and the relative prices of products-especially the huge changes in the prices of energy-these factors are not explicitly addressed in this report.[12]

Summary of Findings

A number of policy issues, such as climate change, disposal of nuclear waste, the trade deficit, acid rain, and military security, are directly tied to energy use. Understanding how energy use has changed is instrumental to designing policies that address these issues. This section draws lessons from the findings in part III and part IV.

Economic Growth and Energy Use

- *Economic growth is not necessarily contingent on using more energy.* OTA analysis finds that between 1972 and 1985 economic growth, at least as it is broadly defined as growth in GDP, was not linked to ever-increasing levels of energy use;[vi] in fact, slow economic growth tended to cause changes that impeded strides towards improving energy efficiency. Although sheer growth, holding all other changes constant, does increase energy use, economic growth never occurs in a vacuum; rather, growth is likely to be associated with other factors such as shifts in the mix of spending towards less energy-intensive products and changes in the way the output of the economy is produced that result in a decline in energy use. Together, these factors contributed to little or no increase in energy use between 1972 and 1985 (table 1).

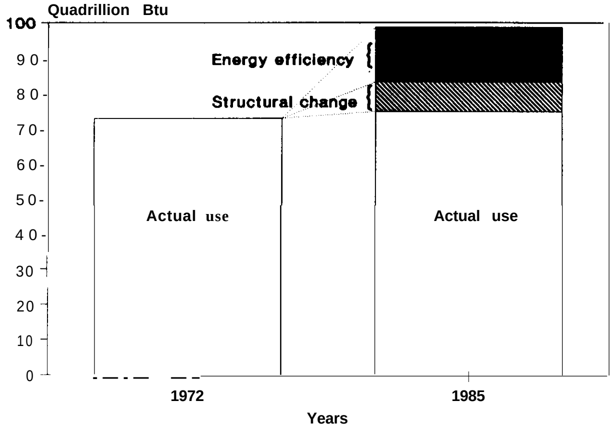
Table l-Changes in Primary Energy Use Due to Selected Factors, 1972-85
(quadrillion Btu)

Actual 1972 to 1985 energy use increase	1.9	
Change due to spending	14.4	
Change due to the level of spending		17.7
Change due to the mix of spending		-5.8
interaction of level and mix		2.5
Change due to production recipe	-19.5	
Change due to the energy portion		-15.4
Change due to the nonenergy portion		-3.7
interaction of the energy and nonenergy		-0.4
interaction of spending and production recipe	7.1	

NOTE: Numbers may not add due to rounding.

SOURCE: Office of Technology Assessment, 1990.

Figure 2-Changes in Energy Use, 1972-85



Actual energy use in the OTA mode, (clear boxes) increased from 72.5 quads in 1972 to 74.9 quads in 1985. Nearly 100 quads would have been used in 1985 if energy savings, because of efficiency improvements (black box) and structural changes (hatched box) in the economy, had not occurred over this period. Of these savings that occurred, nearly two-thirds were because of energy-efficiency improvements in the production processes employed by businesses. The remaining third of the decline, structural change, is indicative of shifts in the industries that make up the economy.

NOTE: This figure does not refleet changes in energy use due to overall growth or interactive factors. See table 1 for these effects.

SOURCE: Office of Teehnoiogy Assessment, 1990.

Energy Efficiency v. Structural Change

- *Energy-efficiency improvements implemented in the production process between 1972 and 1985 mean that the 1985 economy would have used 15 quads more of energy if these gains had not* ***been achieved.*** If these savings had not occurred, the U.S. economy would have required 20 percent more energy in 1985 to produce its output-more than the total amount of energy imports in 1985. (See figure 2.) Two-fifths of these savings came from the manufacturing sector, but another fifth came from the service sector.

- *The leveling of energy use from 1972 to 1985 was not solely due to improvements in energy efficiency, but was also caused by structural shifts in the economy.* Of the factors that offset the increase in energy use due to increases in the sheer size of the economy, nearly two-thirds of the 1972-85 decline was because of energy-efficiency improvements; the remaining third was due to a realignment of the industrial composition of the economy. The output of the economy shifted towards less energy-intensive industries such as services. This shift was caused by changes in the mix of what consumers demanded and by technological improvements in production processes which indirectly saved energy. If these structural shifts between 1972 and 1985 had not happened, the energy used in 1985 would have been about 13 percent higher (9.5 quads).

Direct v. Indirect Use of Energy

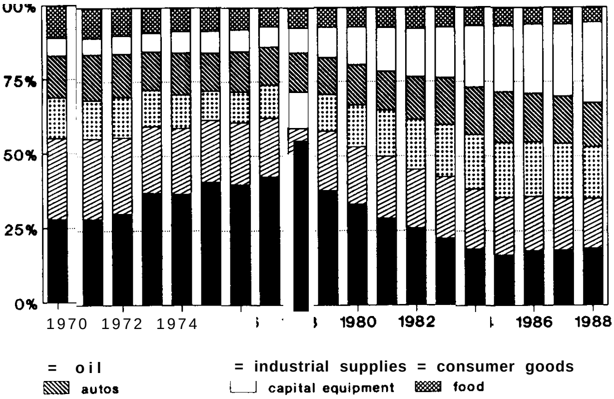
- *Energy is increasingly being consumed indirectly, embodied in nonenergy products, while the growth in the direct use of energy has been relatively small. Of the* increase in energy use between 1972 and 1985 due to spending on all products, only 8 percent was due to direct purchases of energy products like gasoline and

fiIt should be kept inmind that the economic experienee in the 1970s and early 1980s was not free from problems: several reeessions occurred, inflation and unemployment bit very high levels, productivity rates declined, and budget and trade deficits emerged.

heating fuel. The remaining 92 percent of the increase in energy use due to spending was indirectly induced by the purchases of nonenergy products that embody energy like clothes, tires, and automobiles.

- *The bulk of the increase in indirect energy use between 1972 and 1985 came from demand for services.*[vii] Although the energy intensity of the service sector is low, its size and rapid growth have meant that its total energy use is larger than manufacturing 's. The source of much of this indirect demand for energy is personal consumption (households), where indirect demand for energy outpaced direct demand by a factor of 3 from 1972 to 1985.
- *Energy savings can also be achieved indirectly.* Nearly a fifth of the reduction in energy use achieved from 1972 to 1985 because of changes in businesses production processes came indirectly as less energy-intensive inputs like plastic were substituted for more intensive inputs like steel. Almost all of these savings were made in the manufacturing sector.

Figure 3-Major Categories' Share of Merchandise Imports (1982 dollars)



Although the portion of all merchandise imports that are oil has dropped from a high of 42 percent in 1977 to 18 percent in 1988, oil imports are still a higher fraction of constant dollar imports than autos, all consumer goods, or all industrial supplies and materials (which exclude oil).

NOTE: In order to compare the trend over time, the data is presented in constant 1882 dollars. Due to changes in the pffees of some goods sines 1982, like oil, this may have a distorting effect on some categories.

SOURCE: U.S. Department of Commeree, Bureau of Economic Analysis, National Income and Product Accounts, table 4.4.

International Trade

- *Imports of energy products (not including the embodied energy in nonenergy products) are a significant component of our trade deficit.* Although the portion of all imports that are energy ("petroleum and products") has dropped from a high of 42 percent in 1977 to 18 percent in 1988, oil imports are still a higher fraction of constant dollar imports than autos, all consumer goods, or all industrial supplies and materials (excluding oil) (see figure 3).[viii] Of the major merchandise trade categories experiencing a trade deficit in 1988, oil represented almost a quarter of the total[13] and its share seems to be increasing.[14] The share of oil that comes from imports has risen to 44 percent, almost matching our highest level of dependency set at 46 percent in 1977.[15]
- *The United States' gross*[ix] ***energy use*** *would be 9 percent higher if we included the energy embodied in nonenergy imports. The statistics* that show a leveling of domestic energy consumption fail to reflect the fact that the United States indirectly consumes energy by importing nonenergy imports like cars and steel. As the trade deficit has deepened, so has this indirect energy use. OTA estimates that in 1985, the United States consumed roughly 7 quads of energy in nonenergy imports like cars and steel. When this is added to our direct imports of energy, our 1985 foreign energy dependence increases by 50 percent. In terms of recognizing our dependence on foreign sources for energy or our global contribution to problems like climate change, it is important to include estimates of the energy associated with nonenergy imports.[16] Failing to make this adjustment, it would be easy to show declining energy use simply by importing energy-intensive final products and intermediate inputs from abroad. When this adjustment is made, instead of a 39 percent drop in the use of imported energy from 1977 to 1985, the decline is reduced to 21 percent.

[vii]See the appendix for a listing of industries included in the service sector.

[viii]In an effort to show how the composition of imports have changed over time, constant dollar data using 1982 as a base year was used. This creates some distortions in the relative position of products whose prices have undergone a large change since 1982, like oil.

[ix]The energy embodied in nonenergy exports such as grain has not been subtracted.

Differences Between Energy Types

- *Businesses' energy use in the United States is very flexible and adaptable. The* composition of energy use due to changes in production processes has changed dramatically from 1972 to 1985 with the use of crude oil& gas falling by 19 quads over this time period. The drop occurred primarily in manufacturing's use of crude oil & gas,[x] but the energy sector itself and the service sector also made significant contributions to the decline.

- *Declines in energy use were not universal across all energy types.* Energy is not a homogeneous entity, but is instead composed of widely differing products which have very different uses and qualities. The slight increase in overall energy use from 1972 to 1985 came from increases in the use of coal (primarily used to produce electricity) and primary electricity that were largely offset by declines in the use of crude oil& gas and refined petroleum. In aggregate, energy use per dollar of GDP declined from 1972 to 1985, but within individual energy types, all of the decline occurred in crude oil & gas, refined petroleum, and utility gas. Coal and primary electricity registered a slight increase in use per dollar of GDP during this period.

Energy Use From 1985 to 1988

- *The trend of level energy use established from 1972 to 1985 was broken between 1985 and 1988 when energy use increased by 8 percent (5.7 quads). The* energy intensity of the economy stayed constant from 1986 to 1988, dropping at a meager 0.2 annual rate as opposed to the –2.4 percent annual decline achieved from 1972 to 1985.

- Much *of the increase in energy use from 1985 to 1988 can be traced to strong economic growth and a shift in the mix of consumption towards more energy-intensive products. The 1985-88* period was a time of strong economic growth: real GNP grew at an annual rate of 3.6 percent, v. 2.5 percent for the 1972-85 period.

- *The major shifts towards an energy-intensive mix of spending occurred in the government and international sectors.* Federal Government spending on nondefense purchases fell by 16 percent over the 3-year period and defense purchases, which are about 1.5 times as energy intensive as nondefense purchases, grew by 10 percent. Likewise, the energy-intensive export sector experienced the fastest rate of growth of any sector[xi] during this period, increasing its share of GNP from 10 to 13 percent. Even "smokestack" industries like steel and aluminum experienced a resurgence.[17] Overall, exports between 1985 and 1988 grew in real terms by 44 percent while imports increased by only 28 percent.

- *Of the 10 major sectors of the economy,[xii] 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 manufacturing's share of gross output halted a downward trend that had prevailed since 1972.

- *There is little data to support the idea that the 1985-88 increase in energy use was due to less efficient production processes. 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-a period of declining energy use per dollar of output. It is unlikely that these 1985-88 investments caused a reduction in energy efficiency, rather they probably improved energy efficiency, but data detailed enough to confirm this is not available.

Energy Use in the Future

- *Predictions about the rate of economic growth suggest that the increase in energy use should be less in the future than what was experienced between 1976 and 1988. The* annual growth rate of GNP between 1976 and 1988 was 2.9 percent. The Department of Labor's moderate economic growth scenario for 1988 to 2000 assumes a 2.3 percent growth rate.

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[x] Most of this drop actually occurred in the use of refined petroleum products, but this analysis converts all energy use to its primary form which in this case would be crude oil & gas. See part II for a further explanation of this conversion.

[xi] Overall spending consists of five broad sectors: 1) households, 2) business investment, 3) all levels of government, 4) changes in inventories, and 5) international trade (imports and exports).

[xii] The sectors are: 1) agriculture; 2) mining; 3) construction; 4) manufacturing; 5) transportation, communication, and utilities; 6) wholesale trade; 7) retail trade; 8) finance, insurance, and real estate; 9) services; and 10) government.

- *In terms of energy use associated with changes in the composition of output (e.g., structural change) the picture is mixed. The manufacturing* sector is predicted to benefit from increases in exports as the trade deficit narrows, while being hurt by decreases in defense spending as efforts are made to decrease the budget deficit. 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. When viewed across all sectors, changes in energy use associated with changes in the structure of the economy do not appear to be signtificant.
- *The future impact of technology on energy use is even more speculative.* Nevertheless, a wide array of energy-saving technologies that are already in the market are available and hold the potential for significant gains in efficiency. The critical unknowns of the future are not ones of technical potentials, but rather whether the willingness to implement the technology will exist.

The following sections present the analysis behind these findings, showing them over time and breaking the change in energy use down into five energy types: coal, crude oil & gas, refined petroleum, primary electricity, and utility gas. (See part II for further description.) Part III starts with the broad changes that have occurred in energy use due to spending and changes in production processes (labeled production recipe in this analysis). (See part II for definition of terms.) These changes are then broken down into their various components. Changes due to spending are looked at from three angles: level and mix, the sources of spending (e.g., households, government), and the type of product being consumed (e.g., manufactured goods v. services). Production recipe changes are decomposed into changes that directly affect energy use and those changes that indirectly affect energy such as through material substitution. Part IV concludes the report by applying this analytical framework to the recent past (1985 to 1988) and to the near future (1988 to 2000). An appendix, part V, is provided to describe the data, methodology, and strengths and weaknesses associated with the model used for this analysis.

END NOTES FOR PART I

[1]The correlation coefficient of Btu and GDP was 0.992 from 1950 to 1971 which is statistically significant at the 0.01 level. U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts, table 1-2; and U.S. Department of Energy, Energy Information Agency, *Annual Energy Review 1987*, table 4, and the *Monthly Energy Review*, August 1989, table 1-4.

[2]J. Goldemberg, T.B. Johansson, A.K.N. Reddy, and R.H. Williams, *Energy for a Sustainable World*, World Resources Institute, September, 1987, p. 27; and W. Walker, "Information Technology and The Use of Energy," *Energy Supply*, October 1985, pp. 460-461. Some analysts argue that a strong link still exists. See Culter J. Cleveland, Robert Stanza, Charles A.S. Hall, and Robert Kaufman, "Energy and The U.S. Economy: A Biophysical Perspective," *Science*, vol. 225, August 1984, pp. 891-893.

[3]For comparison, the number of housing units in 1970 was 63.4 million, the number of cars and trucks stood at 98 million in 1970, and there were 4.1 million businesses established in 1975. Housing and vehicle data comes from U.S. Department of Energy, *Energy Conservation Trends*, Office of Policy Planning and Analysis, September 1989, p. 2; and the U.S. Department of Commerce, *Statistical Abstract of the United States, 1989* (Washington, DC: U.S. Government Printing Office, 1989), table 1243, p. 706 and table 1011, p. 594, respectively; business establishment data is reported in the *Statistical Abstract of the United States, 1989*, op. cit., table 858, p. 523; energy use data is from U.S. Department of Energy, Energy Information Agency, *Annual Energy Review, 1987* (Washington DC: U.S. Department of Energy, 1988), table 4, p. 13; the source for GDP data is U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts (July 1989 revision), table 1.2.

[4]U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts (July 1989 revision) table 1.2; and U.S. Department of Energy, Energy Information Agency, *Annual Energy Review, 1987* (Washington DC: U.S. Department of Energy, 1988), table 4, p. 13.

[5]This phenomenon is not unique to the United States. It has also been found to have occurred in the United Kingdom, France, Germany, Japan, and Austria. See J. Dunkerley, "Energy Use Trends in Industrial Countries," *Energy Policy* 8 (June 1980); and U.S. Department of Energy, *Energy Conservation Trends*, Office of Policy Planning and Analysis, September 1989, pp. 14-15; C.A. Jenne and R.K. Cattell, "Structural Change and Energy Efficiency in Industry," *Energy Economics*, April 1983, p. 117; C.P. Doblin, "The Impact on Energy Consumption of Changes in the Structure of U.S. Manufacturing, Part I: Overall Survey," working paper, International Institute for Applied System Analysis, Laxenburg, Austria, February 1987, p. 1; U.S. Department of Energy, *Energy Conservation Trends*, Office of Policy Planning and Analysis, September 1989, p. 15; A. Kahane, "Industrial Electrification: Case Studies of Four Industries," revised summary, October 1986; C. Lager, K. Musil, and J. Skolka, "Input-Output Analysis of Energy Conversion in Austria, 1955-1980," *Proceedings of the Fourth IIASA Task Force Meeting on Input-Output Modeling* (Laxenburg, Austria: IIASA, 1983), p. 287.

[6]For example, see C. Komanoff, "Increased Energy Efficiency: 1978-1986," *Science*, vol. 239, No. 4836, Jan. 8, 1988, p. 128; U.S. Department of Energy, Oak Ridge National Laboratory, *Energy Efficiency How Far Can We Go?* ORNL/TM-11441, January 1990, p. 1; and World Resources Institute, press release, "U.S. One of the World's Least Energy-Efficient Countries," Nov. 20, 1989.

[7]For more on how the structure of the U.S. economy has changed over the last decade-and-a-half, see U.S. Congress, Office of Technology Assessment, *Technology and the American Economic Transition: Choices for the Future*, OTA-TET-283 (Washington, DC: U.S. Government Printing Office, May 1988), ch. 5.

[8]Huntington and Myers found that at least one-third of the decline in energy intensity in the manufacturing sector from 1973 to the early 1980s was due to sectoral shifts. See G.H. Huntington and J.G. Myers,

"Sectoral Shift and Industrial Energy Demand: What Have We Learned?" p. 1; Hirst et al. found that a third of the industrial decline in intensity between 1972 and 1981 was due to sectoral shift. See E. Hirst, R. Marlay, D. Greene, and R. Barnes, "Recent Changes in U.S. Energy Consumption," *Annual Review of Energy*, vol. 8, 1983, p. 224; Doblin found that for the 1974 to 1980 period changes in structure accounted for half of the decline in energy intensity in the manufacturing sector. See C.P. Doblin, "Declining Energy Intensity in the U.S. Manufacturing Sector," *The Energy Journal*, vol. 9, No. 2, 1988, pp. 23 and 33; Boyd et al. found that for the manufacturing sector, structural changes accounted for about 16 percent of the 1971 to 1981 drop in energy use. See G. Boyd, D.A. Hanson, and M. Ross, "The Market for Fuels in the U.S. Manufacturing, 1959-81: Effects of Sectoral Shift and Intensity Changes," draft prepared for the Energy Modeling Forum Study 9, September 1987, p. 20; Williams, Larson, and Ross find that the decline in industrial energy intensity between 1973 and 1985 was due almost equally to efficiency gains and structural shifts. R.H. Williams, E.D. Larson, and M. Ross, "Materials, Affluence, and Industrial Energy Use," *Annual Review of Energy*, 1987, p. 100. For a survey of the literature analyzing the importance of structural shifts on industrial energy use, see G.H. Huntington and J.G. Myers, "Sectoral Shift and Industrial Energy Demand: What Have We Learned?" *The Changing Structure of American Industry and Energy Use Patterns*, A. Faruqui, J. Broehl, C. Geilings (eds.) (Columbus, OH: Battelle Press, 1985).

[9]A notable exception to this is the work authored by J. Roop. See U.S. Department of Energy, "Energy's Role in International Trade: Structural Change and Competitiveness," Office of Policy Planning and Analysis, July 1989.

[10]*Technology and the American Economic Transition: Choices for the Future*, op.cit., endnote 7, p. 160. The remaining 6 cents goes to construction, personal services, and social services.

[11]For example, DuPont has initiated a "Quick Response" system that ties the clothing retailer to the apparel manufacturer to the textile producer. See *Technology and the American Economic Transition: Choices for the Future*, op. cit., endnote 7, p. 238.

[12]For two different analysis of the how changes in the price of energy affect the economy, see Douglas R. Bohi, *Energy Price Shocks and Macroeconomic Performance* (Washington, DC: Resources for the Future, 1989); and Sam H. Schurr, "Electricity Use, Technological Change, and Productive Efficiency," *Annual Review of Energy*, vol. 9, pp. 409-425.

[13]U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, National Income and Product Accounts, table 4.3.

[14]Petroleum and petroleum products share of merchandise trade imports (not seasonably adjusted) increased from 7.7 percent in November 1988 to 10.8 percent in November 1989. U.S. Department of Commerce, Bureau of the Census, "U.S. Merchandise Trade," news release, Jan. 17, 1990, exhibit 5.

[15]U.S. Department of Energy, Energy Information Agency, *Monthly Energy Review*, November 1989, table 1.8, p. 15.

[16]For example, policies that set a specific reduction in energy intensity should take this into account. See W.U. Chandler, H.S. Geller, and M.R. Ledbetter, *Energy Efficiency: A New Agenda* (Springfield, VA: George Washington Press, 1988), p. 21 for an example of such a policy.

[17]Exports of steel mill products increased by 121 percent from 1985 to 1988 while imports of steel mill products decreased by 14 percent. Aluminum exports increased by 44 percent and imports fell by 5 percent over this period. American Iron and Steel Institute, *Annual Statistical Report, 1988*, 1989, tables 14 and 18, pp. 34 and 44. The Aluminum Association, *Aluminum Statistical Review for 1988*, No. 94, 1989, p. 5.