Energy and Economic Growth in the United States

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The Institute for Energy Analysis was established in 1974 as a division of Oak Ridge Associated Universities to examine broad questions of energy policy. More specifically, it assesses energy policy and energy research and development options and analyzes alternative energy supply and demand projections from technical, economic, and social perspectives. The Institute focuses primarily on national energy issues, but it is also concerned with international energy questions and their implications for domestic energy problems.

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and what inferences are being drawn from these assumptions. In this respect, I find these semiquantitative methods of prognostication more appealing than the more heavily econometric schemes that are in such vogue now. Too often the entire econometric analysis hangs on a single number—typically, the elasticity of demand for liquid fuels; and the results are correspondingly fragile, since demand elasticities are notoriously unreliable.

The publication of *Energy and Economic Growth in the United States* in 1979, some 3 years after much of the underlying work was completed, has a disadvantage: one can begin to compare the predicted and actual turn of events. As for total energy demand, the low estimates seem to be tracking the actual trend. On the other hand, the original estimates for nuclear power have been much too high; this striking change is reflected in this volume but not in its earlier companion moratorium study.

Dr. Allen has done a substantial service for the community of energy analysts in creating order from a mass of seemingly unrelated and disordered data. He has acknowledged most gracefully his debt to his colleague, Dr. Charles Whittle, Assistant Director of the Institute for Energy Analysis, who formulated the semiquantitative scheme for projecting energy demand that has been applied so well by Dr. Allen. I wish to extend my thanks to Drs. Allen and Whittle, as well as to the other members of the Institute for Energy Analysis, who in this volume have made a useful contribution to the literature of energy analysis.

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INTRODUCTORY NOTE

Energy and Economic Growth in the United States is the second volume in the Institute for Energy Analysis–MIT Press series entitled *Perspectives in Energy*. It is a companion to the first volume, *Economic and Environmental Implications of a U.S. Nuclear Moratorium, 1985-2010*, which was published in 1976. The moratorium study was based on estimates of future energy demand; the present study explains in detail how the Institute for Energy Analysis arrived at these estimates.

The relation between energy and economic well-being is central to energy analysis. This relation was first examined in detail in the book *Energy in the American Economy, 1850-1975* by Schurr, Netschert, Eliasberg, Lerner, and Landsberg that appeared almost 20 years ago. Remarkably, the estimated aggregate energy demand for 1975 given in this book agreed almost perfectly with the actual energy used in that year. Yet the methods used in making these estimates were rather qualitative and bore little resemblance to the "hard" econometric analysis that now pervades the literature of future energy predictions.

The methods used in this volume are much closer to those used in the early study of Schurr *et al.* than they are to, say, the very elaborate econometric modeling of the Project Independence study. One cannot claim that the use of these methods confers on these estimates a greater likelihood of accuracy. Nevertheless, the methods used in this volume have the advantage of transparency: one can see at each stage precisely what assumptions are being made

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SUMMARY

New Findings Since the 1976 Report

Since the Institute for Energy Analysis (IEA) released its initial report on *U.S. Energy and Economic Growth, 1975-2010,* in 1976, a number of supplementary reports have been completed and their conclusions are embodied in this book. These changes and additions are as follows:

1. We have now identified that perhaps the single greatest uncertainty in our earlier and current estimates is the size of illegal immigration. If the net influx of illegal immigrants is approximately 10^6 a year, a number some observers believe corresponds to present experience, the U.S. economy might grow at higher rates than those estimated here. This potential uncertainty has been analyzed and is reported in Appendix A.

2. At the time of our earlier report, coal seemed assured of a larger and rapidly growing share of the public utility and industrial fuel markets. This outcome is now much less certain, even though the long-term competitive position of coal appears to have improved significantly. Costly federally mandated pollution controls and a host of federal laws dealing with mining regulations, combined with sharply higher labor costs, have dulled coal's competitive edge.

3. Detailed regional energy and economic estimates for the year 2000 are included for the 101-quad case. There is great regional variation in energy use per capita; the largest differences are due to the concentration of energy-

intensive industries in a few locations. Other factors are variations in climate and population density. Four regions, the West South Central, East North Central, Middle Atlantic, and South Atlantic, will account for 67 percent of the anticipated national total in 2000 (see Chapter 5).

4. Having subsequently analyzed the impact on energy demand of an aging population and of rising employment in the service industries in more detail, we do not now concur in the commonly held views that these developments are likely to lower the aggregate ratio of energy use to the gross national product (GNP) over the next few decades. We now conclude that the energy impact of an aging population will be toward higher per capita consumption of energy, largely because these adults are in the active work force which constitutes the highest per capita energy-consuming group. They will account for 60.4 percent of the total population in 2000 compared to 53.6 percent in 1975.

5. A detailed examination of the probable growth rates and projected energy efficiency improvements of several major energy-consuming manufacturing industries has led to a much lower estimate of industrial energy demand, some 44.4 quads of total industrial demand in 2000 compared to 50.3 quads estimated in the 1976 study. The earlier estimates of likely household and commercial energy savings by 2000 are believed to have been overstated by perhaps 20 percent.

The Energy Problem

In the historical sweep of the economic growth and development of the United States, energy has been considered a nearly ubiquitous good—essential, to be sure, but abundant and inexpensive. Yet, as the decade of the 1970s opened, there were some warning signals that the era of abundance was coming to a close. Petroleum production in the United States peaked in 1970. The output of domestic natural gas, which supplied the largest share of energy for the economy, peaked in 1972. The embargo imposed in late 1973 by the Organization of Petroleum Exporting Countries (OPEC) on oil exports to the United States dramatically signaled the end of the era of self-sufficiency. The effectiveness of the embargo was made possible by a basic change in America's domestic energy industries, from a comfortable surplus of supplies to a growing dependence on imports. Energy prices, led by oil prices, escalated rapidly.

At the same time, official and private forecasts of future energy demands, based largely on recent historical growth rates of 3.7 percent a year, moved upward relentlessly. The consequence was the predicted emergence of a gap between world oil production and requirements by the early 1980s, which was expected to grow to alarming proportions by the end of the 1980s. If these estimates were correct, economists in the U.S. Department of Energy and the Central Intelligence Agency believed that U.S. economic growth would be severely affected because of a shortage of essential energy.

One of the major conclusions of the IEA studies is that, although there is a serious energy problem, it can be eased by conservation and the stimulation of new sources of supply. Therefore, even though energy prices seem certain to rise, both absolutely and relatively, we have not been able to identify an inevitable supply/demand "crunch" which will produce economic disruption and record high unemployment in this century.

Specifically, this study estimates economic growth (GNP) and energy demand for the United States to the year 2000. We find that the GNP and total energy demand are likely to grow more slowly than has been forecast in most analyses of energy policy sponsored by the U.S. government. Instead of basing our estimates on economic growth rates that are tied to highly optimistic full employment goals, our aim has been to construct what we believe are the most likely economic scenarios and the related future energy needs. Thus, the estimates that emerge from our analysis are in no sense "normative"; we have avoided suggesting what *ought* to be the U.S. energy future. Rather, our estimates flow from an analysis of what we believe is *likely* to happen in a surprise-free world. As has been generally noted, differences in economic growth assumptions exert large effects on calculations of energy requirements.

Many factors point to a lower economic growth rate in the next 20 to 25 years than this country has enjoyed since the onset of World War II, as is explained in Chapter 1. These factors include the sharp drop in the fertility rate during the last decade, which will cut the growth of the labor force by 50 percent by the end of the 1980s in the absence of massive immigration, and a drop in productivity and productive investment that will make productivity gains that occurred in the past more difficult to achieve. Lower energy demands are likely to occur as a result of reduced economic growth, the gradual introduction of energy-saving technologies, and the expected higher energy prices. Although accurate prediction of the future is clearly impossible, many of the underlying factors that will bear heavily on economic growth and energy demands in the decades immediately ahead can now be specified.

Throughout this study we have endeavored to explain precisely the methods used and the reasons for arriving at given estimates. Each reader can then decide for himself the extent to which he would accept or modify the analysis. Long-term energy and economic projection is not a pure science but rather an art based on economic and technological assessments and reason.

Methodology

A summary of our methodology is given in the next several paragraphs. The U.S. energy demands are divided into four broad sectors—households, commercial space, the transportation of persons and goods, and industry. We determined the future growth of energy demands in each sector by combining demographic-economic assumptions with attainable technical efficiencies in specific energy-consuming devices and calculated the rates for the introduction of these newer technologies. The specific energy demands obtained from an analysis of each sector were then summed to obtain the total energy demand.

We arrive at our estimates of energy demand in four specific steps. First, we estimate the GNP (in Chapter 1) by using a simple formulation: GNP equals labor force multiplied by labor productivity. The employed labor force and the hours worked are estimated from projections of population and labor participation rates. The adult population is already determined for much of the period (up to the early 1990s), and the labor participation rate (the number of persons 16 years and older who are either employed or actively seeking employment compared to the total number of persons 16 years and older) is assumed to continue its long-term growth. Labor productivity (the output per worker) is estimated by extrapolation of historic trends. In general, we have tried to bias our results toward the high side. For example, we have used optimistic assumptions about future labor productivity. In Chapter 2, we have been conservative in our judgments regarding future energy conservation.

From projections of the GNP and population, we derive estimates of the size of intermediate factors leading to the energy demand calculations shown in Chapter 3. That is, we calculate the number and type of households expected in the year 2000, the square feet of commercial space needed to support these households, and the number of automobiles expected to be on the road. Since automobile use is a consequence of life-style decisions, which are uncertain, we project two possible trends. One of these, used in the low

(101-quad) scenario, assumes that automobile usage has reached a point of saturation in relation to the population of driving age and that the annual mileage per automobile will remain at 1975's 10,000 miles. The second assumption, used in the high (126-quad) scenario, is that the automobile stock will increase from the present 0.67 car per person over 16 years of age to 0.77 by the year 2000. In addition, the annual mileage per vehicle is allowed to increase from 10,000 to 12,000 miles in 2000.

From the magnitudes of each intermediate factor, we estimate its corresponding end-use energy demand; the total energy demand is then the sum of the energy demands in each end-use category. Two parameters enter into these estimates: the rate of introduction of new technologies (for example, lightweight automobiles) and the degree of energy conservation (the so-called efficiency improvement index). Our projections of population, GNP, and energy demand are shown in Table 1.

We have given independent estimates of energy prices, based generally on extrapolation and judgment instead of explicit prices of energy. Implicit in

Table 1.

Population, GNP, and energy demand estimates for the low (101-quad) and high (126-quad) scenarios

	Totals					
	Population ($\times 10^6$)		GNP ($\times 10^9$ \$1972)		Energy (quads)	
Year	Low	High	Low	High	Low	High
1975	213	213	\$1192	\$1192	71	71
1985	229	231	1730	1730	82	88
2000	246	254	2620	2648	101	126
	Per capita values					
	GNP (\$1972)		Energy demand ($\times 10^6$ Btu)			
1975	\$ 5,596	\$ 5,596	334	334		
1985	7,555	7,490	360	381		
2000	10,650	10,425	411	496		

our energy demand projections are price elasticities, and we find our calculated elasticities to be well within the range of elasticities obtained in other studies.

Assumptions

Given the unknowability of the future, we chose to estimate energy demand according to two scenarios, low and high. The assumptions underlying the two scenarios for each of the elements that determine energy demand are summarized in Tables 2, 3, and 4. Table 2 lists the assumptions made for the key factors that contribute to the growth and composition of the population, the labor force, and GNP. (The specific assumptions underlying Table 2 are discussed in detail in Chapter 1.) Table 3 lists the assumptions made for the key factors determining growth in the intermediate factors for households, commercial (service) space, and automobile inventory. Table 4 lists the assumptions made for the changes in the end-use efficiencies for different energy-use categories. Each of the assumptions is represented by values for selected years between 1975 and 2000.

Our analysis begins with a detailed examination of historic trends for the many factors that determine the growth of the GNP and energy demand. One major factor that implies a lower GNP path is the fertility rate (average number of children per female), which has fallen to 1.8 and is likely to continue at approximately that level. Low fertility will contribute to a slower growth of the labor force, in the absence of higher levels of immigration.

Productivity has been growing much more slowly in the 1970s than it did historically. The reasons for the slower growth rate are not fully understood, but the snowballing costs of pollution abatement and safety requirements, which do not contribute output to the GNP in the conventional sense, have been identified as contributing factors. In spite of other pessimistic factors affecting productivity, we have projected an optimistic recovery of productivity rates between now and the year 2000 from a current 1.8 percent annually to 2.6 percent in the years 1985 through 2000.

In the lower estimate of total energy demand for the year 2000, we have assumed a rapid but far from maximum introduction of energy-saving devices and more efficient technologies. In the higher projection, the pace of conservation is more leisurely. We regard both of these improvements as achievable without a change in life-styles.

Table 2.

Summary of key input assumptions for population, labor force, and GNP growth for the high- and low-energy demand scenarios

Year or period	Fertility rate (children/female) Low	Fertility rate (children/female) High	Labor participation rate (workers per persons 16 and over) (Low and high)[a]	Annual growth rate of full-time employment (%) Low[a]	Annual growth rate of full-time employment (%) High[a]
1975	1.8	1.8	0.61		
1975-1985				1.6	1.6
1985	1.7	1.9	0.625		
1985-2000				0.8	0.8
2000	1.7	1.9	0.635		

Period	Annual growth rate of average labor productivity (%) Low	Annual growth rate of average labor productivity (%) High	Annual growth in GNP (%) Low	Annual growth in GNP (%) High
1975-1985	2.0	2.0	3.8	3.8
1975-2000	2.6	2.6	2.8	2.8

[a]Immigration in each case is assumed to be the same (400,000 per year) as recent Bureau of the Census population projections. The unemployment rate is assumed to fall to 5 percent.

Table 3.

Intermediate factors for households, services, and automobiles

Year	Households per adult[a] (low and high)	Commercial space per household[b] (square feet) (low and high)	Autos per person over 16 years[c]	
			Low	High
1975	0.53	350	0.67	0.67
1985	0.55	385	0.65	0.71
2000	0.57	437.5	0.65	0.77

[a]Single-person households are assumed to shift to smaller average size housing units.

[b]Commercial composition is assumed to shift from education-type units toward health care and recreation units.

[c]Automobiles are assumed to shift toward lighter-weight vehicles.

Table 4.

Average energy use efficiencies

Year	Households (x 10^6 Btu/unit)		Commercial (x 10^5 Btu/square foot)		Automobiles (miles per gallon)	Truck or bus or rail freight (x 10^3 Btu/ton-mile)	Industrial index (compared to 1975)	
	Low	High	Low	High	(low and high)	(low and high)	Low	High
1975	219	219	3.69	3.69	14	7.1	1.00	1.00
1985					20	6.8	0.85	0.90
2000	214	285	2.82	3.63	27	6.3	0.70	0.80

Findings

Two projections for population, labor force, and GNP are given in Table 5. These projections are based on the analysis in Chapter 1 and the assumptions listed above for future fertility rates, labor participation rates, and labor productivity.

Projections of the number of households, commercial space, and the inventory of automobiles are listed in Table 6. These results are based on the analysis in Chapter 2 and the assumptions for future household formation rates, commercial space and type, and automobile ownership and use listed above.

The key finding is that energy demand over the next 25 years is likely to grow more slowly than in the past and that the ratio of energy use to the GNP will be improved. We also find that the demand for electricity is likely to rise faster than the total demand for energy. Table 7 presents energy demand by sectors. Certain more important findings may be summarized as follows:

1. Long-term average U.S. economic growth after 1985, in terms of real GNP, is likely to be in the range of 2.6 to 3.0 percent annually, even with optimistic assumptions about future growth in labor productivity, unless the flow of illegal aliens into the labor force is very high. This compares to an average annual rate of growth of 3.4 percent for the GNP during the past 35 years.

2. Future long-term growth in U.S. energy demands, even with moderate assumptions about conservation, is likely to be in the range of 101 to 126 quads by the year 2000 if net average energy prices increase at an anticipated annual rate of 2.3 to 4.3 percent and the price increases are gradual and anticipated.

3. The projected growth in the GNP implies that the per capita GNP growth will range from 2.4 to 2.6 percent annually, compared to a growth rate of only 1.8 percent over the past 35 years. The projected annual growth in per capita energy use will range from 1.0 to 1.7 percent compared to 1.4 percent for the past 35 years.

4. Energy-demand scenarios developed here imply a shift to a greater use of electricity, from a current 28 percent of the total to over 46 percent by the year 2000.

5. An analysis of future energy prices and elasticities produces the values shown in Tables 8 and 9.

Table 5.
Population, labor force, and GNP growth

Year or period	Population (x 10^6) Low	Population (x 10^6) High	Labor force (x 10^6) (low and high)	GNP (x 10^9 $1972) Low	GNP (x 10^9 $1972) High	Annual growth in GNP (%) (low and high)
1975	213	213	95	$1192	$1192	
1975-1985						3.8
1985	229	231	111	1730	1730	
1985-2000						2.8
2000	246	254	124	2620	2648	