EMF 8 PROJECIONS OF U.S.
INDUSTRIAL ENERGY DEMAND

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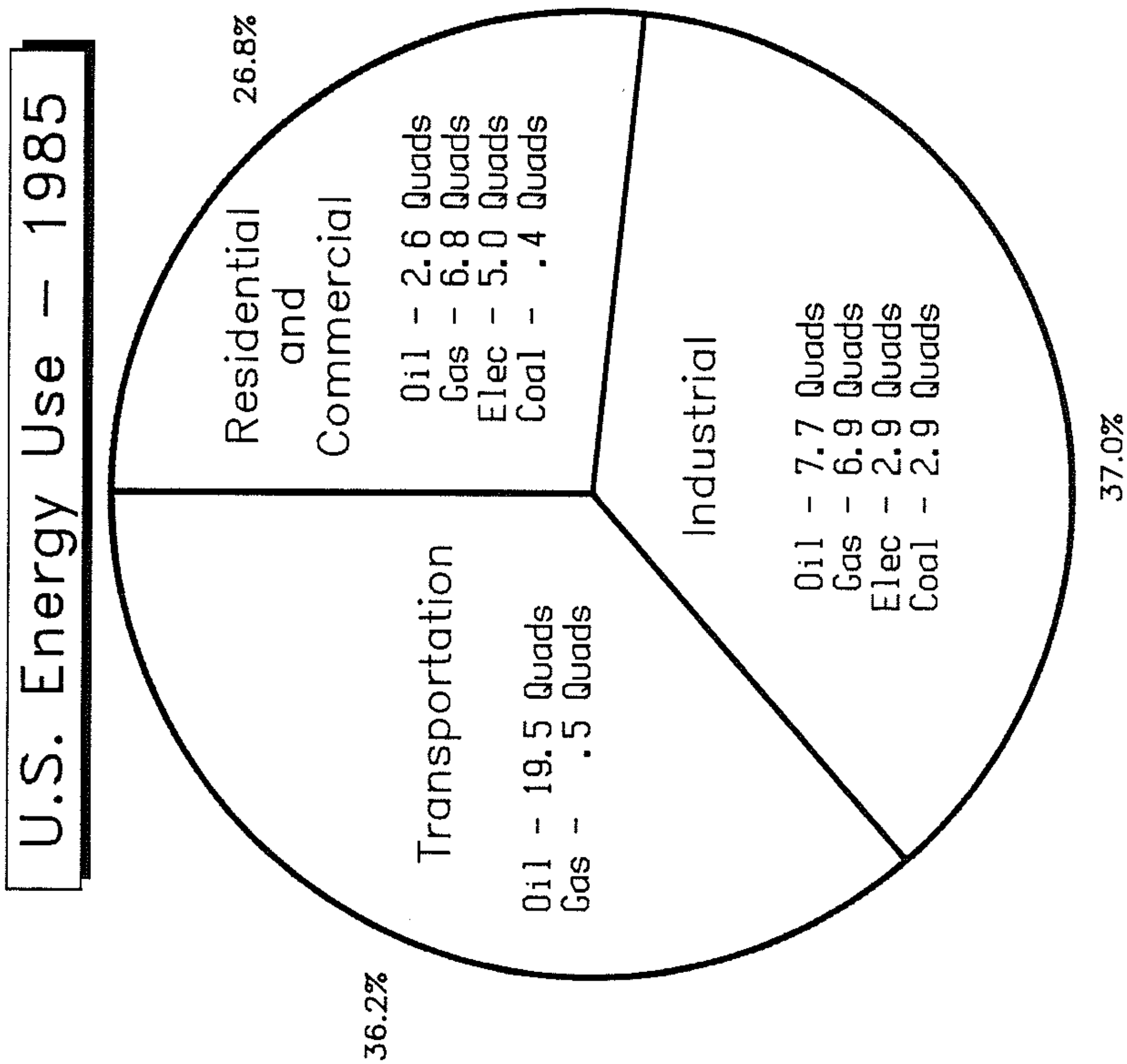
1. INTRODUCTION

The demand for energy by U.S. industry plays a critical role in determining fuel prices in oil, gas, and electricity markets. OPEC oil production policies are the single most important determinant of crude oil prices. However, changes in world oil demand have been significant unexpected sources of change in OPEC's capacity utilization, a major determinant of its production and pricing policies. Moreover, changes in fuel consumption patterns by U.S. industry drive the fluctuations in the prices of other fuels that occur over their long adjustment to changes in crude oil prices. The oil price collapse of 1986 has again lead to dramatic changes in all fuel markets, making it even more important to reexamine trends in industrial energy use.

Industrial energy demand projections are of great interest to a variety of planners. Capital investment decisions are often based in part on energy prices which in turn are affected by total energy demands. Energy suppliers choose production and pricing strategies by considering customers' demands. Government energy policies depend on estimates of future energy demands and the impacts that regulations will have on the economy.

Although making accurate industrial energy demand projections is important, it is not easy. Industrial energy demand is affected by a large number of factors, most of which are not controllable by any one individual or group. Decisions on energy-related investments - like any other corporate investment decisions - can depend as much on financing considerations and the state of the economy as on expected energy prices. However, the sheer magnitude of the industrial sector's energy consumption

Figure 1: U.S. Energy Consumption by End Use Sector - 1985



insures its central role in determining future fuel prices, even if energy prices are not the most critical determinant of its energy use. In 1985 the industrial sector used approximately 20 quadrillion Btus of direct fuel, electricity, and fossil fuel feedstock, nearly 40 percent of all energy consumed in the United States (see Figure 1). And this 40 percent figure significantly understates the role of the industrial sector in U.S. energy demand because a large part of the commercial sector provides services to industry, and a significant share of the transportation sector is devoted to the transportation of industrial supplies and products.

Both energy prices and economic growth have been erratic since the 1973-1974 Arab oil embargo. Fundamental innovations in the production of all types of commodities appear literally overnight in this era of high technology and increased international competitiveness. Foreign competition provides challenges in world markets once dominated by American products. These and other factors are important determinants of U.S. industrial energy demand. Uncertainties in these areas make projecting industrial energy demand a difficult challenge.

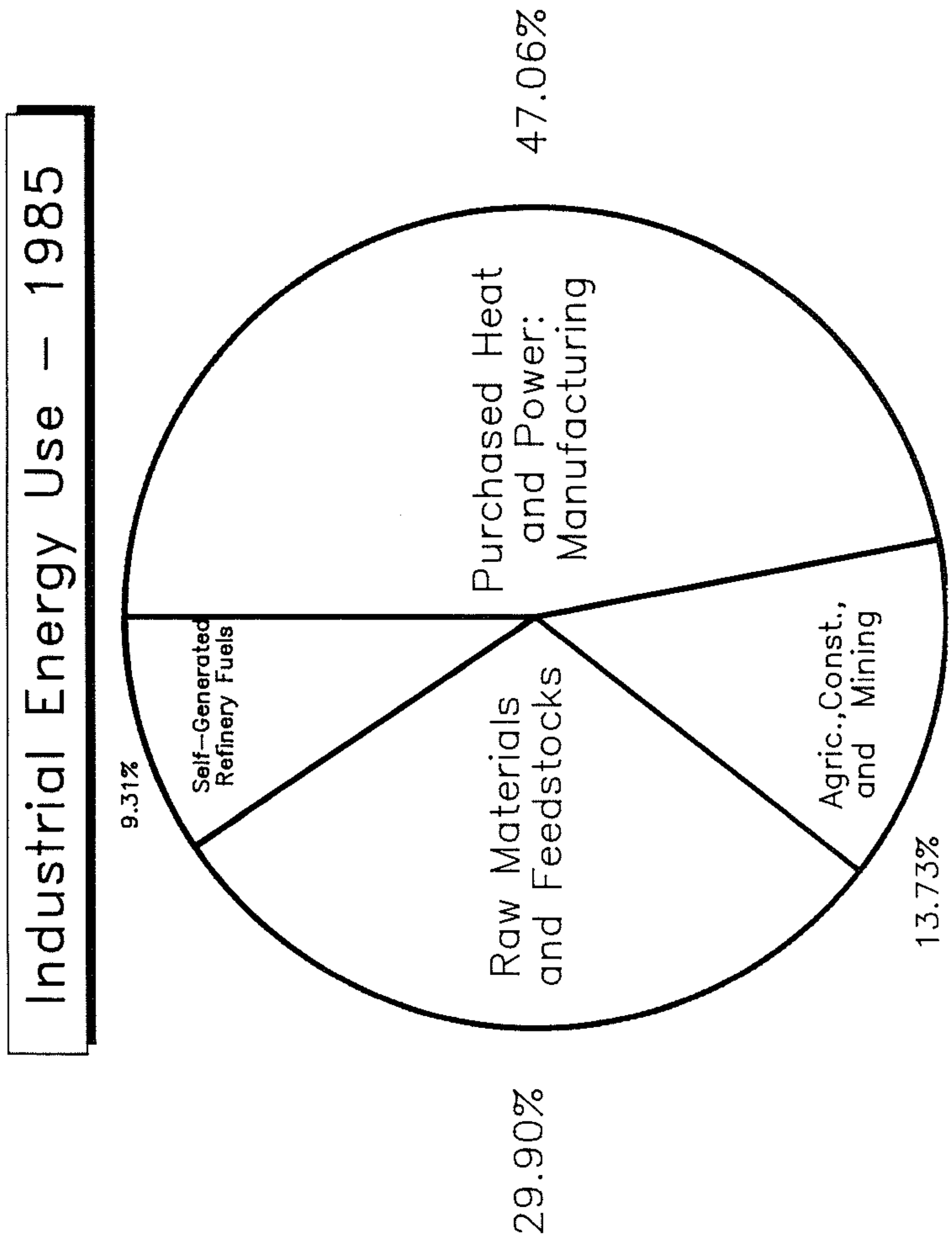
The EMF 8 project examined these issues and their implications for industrial energy demand through a study of models of industrial demand currently in use. These models represent the state of the art in aggregate projections of future energy demand. The methodologies employed in these models include econometrics, input-output analysis, and process analysis. Projections derived from a standardized base case and a variety of alternative scenarios were used to examine the possible effects of the key uncertainties affecting industrial energy demand. Through this process, insights were gained about the strengths and limitations of the specific modeling efforts included in the study and, perhaps more importantly, about the likely level and composition of industrial energy demand in the years ahead. A range of possible energy/technology futures was examined by dealing explicitly with the uncertainty about factors affecting future industrial energy demand. Contingency planning is facilitated when these uncertainties are recognized and allowance is made for them in making investment decisions. Ultimately, this process can lead to a better appreciation of the forces governing industrial energy demand and to better energy policies.

In addition to the standardized model comparisons, this EMF working group pursued three topics related to the use of analysis in the study of industrial energy use trends: (1) the appropriate use of models by corporations involved in producing or consuming energy; (2) the availability and appropriate use of data on industrial energy use; and (3) the impact of the changing structure of the U.S. economy on the use of energy by U.S. industry.

2. OVERVIEW OF U.S. INDUSTRIAL ENERGY USE

In 1985 U.S. industry purchased 9.6 quadrillion Btus (quads) of fuels for heat and power in manufacturing out of a total of 20.4 quads of industrial energy use; the difference being comprised of 2.8 quads of energy use in agriculture, construction, and mining, 6.1 quads in raw materials and feedstocks, and about 1.9 quads of self-generated fuels used in refineries. Figure 2 shows the breakdown of total industrial energy use according to these basic functional use categories.

Figure 2: Industrial Energy Use - 1985



Most data collection and modeling efforts concerning energy use in the industrial sector have focused on the analysis of energy purchased for heat and power in manufacturing. The manufacturing heat-and-power sector tends to dominate the use of gas and electricity in industry and it is here that the competition amongst oil, gas, coal, and electricity is most intense; in recent years, however, oil consumption has been concentrated outside of this sector. Table 1 shows the breakdown of fuel use in 1985 within each of the four aggregate fuel use categories identified in Figure 2. EIA's Annual Energy Review 1985 shows 6.6 quadrillion Btu of oil use in industry in 1985, of which only 1.0 was for purchased heat and power in manufacturing and only 0.4 of that for residual oil (i.e., boiler fuel and the like). Thus, to project oil demand and oil market conditions, it is especially important to focus on the demand for energy in the agriculture, construction, and mining industries, as well as on the demand for chemical feedstocks.

Primary data from the Census Bureau, the Department of Agriculture, the Energy Information Administration, and the Bureau of Mines shows a trend towards increasing use of energy per unit of output for agriculture, construction, and mining over the last decade. The energy-output ratio has been constant in two areas, crop drying and quarrying. This is what one might expect, since there has been little depletion of stone and gravel, and no diminishing returns problems with crop drying. On the other hand, in oil and gas production--an important part of the mining sector--the need for more and deeper drilling to sustain existing production has lead to an increase in fuels used by drill rigs and related equipment. In addition, electricity use in irrigation has been growing exponentially.

Table 1
Industrial Fuel Demands - 1985*
(Quadrillion Btus)

	Petroleum Products	Natural Gas	Coal	Purchased Electricity	Self-Generated Fuels	Total
Heat and Power Manufacturing	1.0	4.5	1.7	2.4	1.9	11.5
Feedstocks	4.4	.6	1.1	-		6.1
Agriculture, Construction, and Mining	1.2	1.0	.1	.5		2.8
TOTAL	6.6	6.1	2.9	2.9	1.9	20.4

* Preliminary estimates.

Fuel use for raw materials is also important. A quad is used for metallurgical coal. This is generally expected to decrease, because of the switch to electric-based technologies in the steel industry. Most of the rest is for oil and natural gas liquids, including about 3.0 quadrillion Btus of petrochemical feedstocks in 1985.

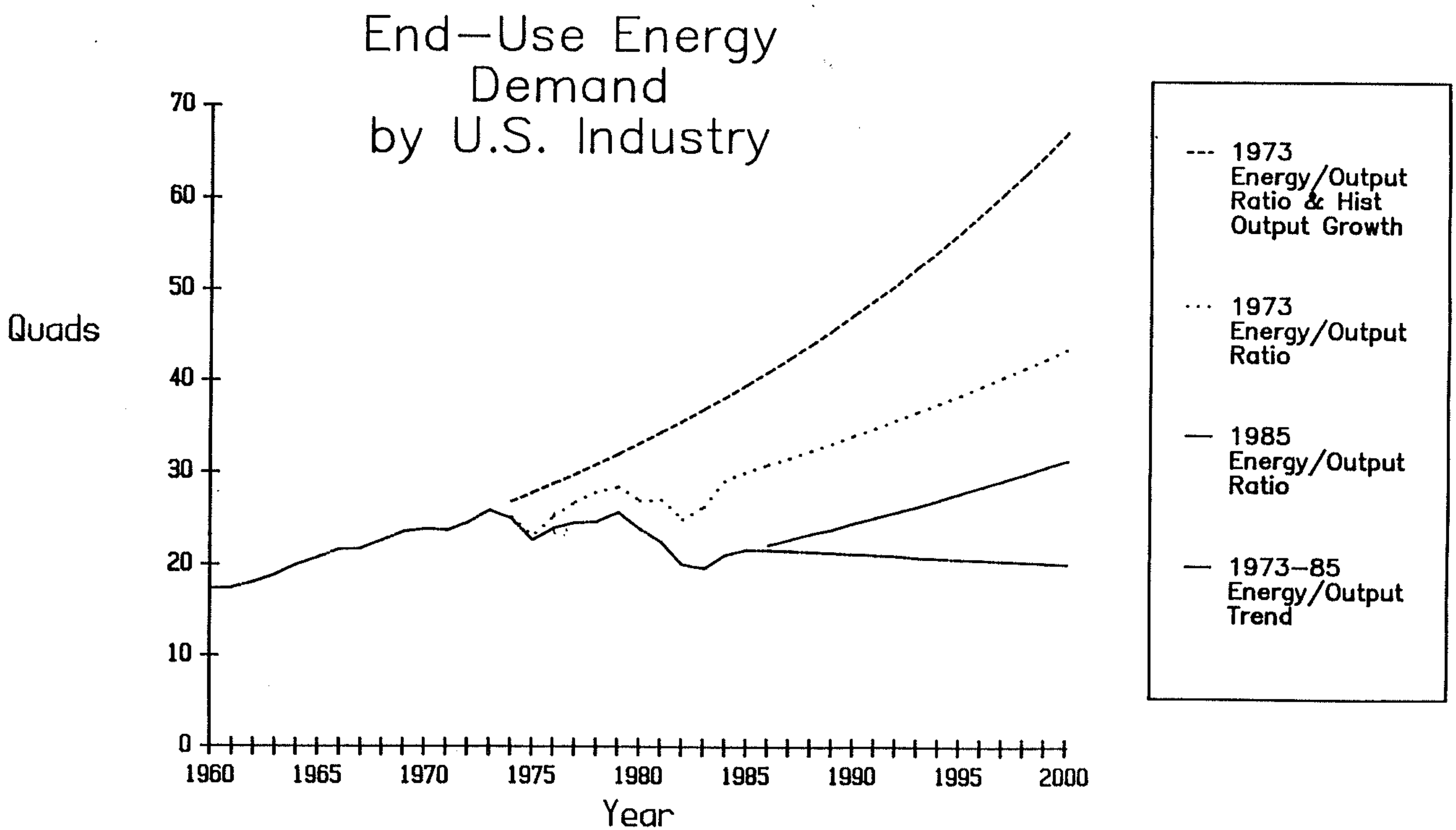
About two quads of self-generated fuels (mostly still gas) were used in U.S. refineries in 1985. In addition to these self generated fossil fuels, a significant quantity of biomass and waste products were used as fuels. In the paper industry (SIC 26), a very energy intensive industry, about half of the energy consumed was waste pulping liquor and biomass, both of which are by-products of the raw materials (mostly wood) processed in the industry. These non-fossil fuels are omitted in Figure 2 and Table 1.

3. HISTORICAL TRENDS IN INDUSTRIAL ENERGY USE

Past trends in energy use by U.S. industry provide a useful benchmark for any attempt to project future trends. Figure 3 shows actual end-use energy demand by U.S. industry from 1960 to 1985 as well as four trend extrapolations through the year 2000.

Industrial end-use energy demand grew from 17 quadrillion Btus in 1960 to 26 quadrillion Btus in 1973, an average annual growth rate of 3.1 percent. During this period real industrial output grew at an average annual rate of 3.6 percent per year, so end-use energy per unit of output was declining very slowly at about .5 percent per year. Had these trends continued end-use energy demand by industry would have reached nearly 40 quadrillion Btus by 1985 and over 60 quadrillion Btus by the year 2000.

Figure 3: Industrial Energy Use Trends



Part of the reason that actual energy demand growth slowed between 1973 and 1985 was that industrial output grew much slower during that period than during the sixties and early seventies. In fact, real output grew at only 1.4 percent per year from 1973 to 1985 compared to its 3.6 percent annual growth rate between 1960 and 1973. Figure 3 shows that with actual output growth and the energy output ratio fixed at its 1973 level, industrial demand for end-use energy demand would have reached approximately 30 quadrillion Btus by 1985. In addition, if real output grew at 2.5 percent per year from 1985 to 2000 after reaching 30 quadrillion Btus in 1985, demand would reach 44 quadrillion Btus by 2000.

As shown in Figure 3, actual end-use energy demand by U.S. industry fell from 26 quadrillion in 1973 to 20.4 quadrillion Btus in 1985, an average annual decline of 2.0 percent per year. With output growth at 1.4 percent per year, this implies a 3.4 percent reduction in the energy-output ratio during the post-embargo period.

Two additional trend extrapolations based on a 2.5 percent growth in real output between 1985 and 2000 are shown on Figure 3. In one, the 1973 to 1985 reduction in energy output ratio of 2.9 percent per year continues yielding a further reduction in energy use to 20 quadrillion Btus by 2000. In the other extrapolation, the energy-output ratio is fixed at its 1985 level so energy demand grows at 2.5 percent per year reaching 31 quads by 2000.

None of the four trend extrapolations shown in Figure 3 represents a forecast of the future. They do, however, provide a useful perspective on future energy use. If energy use per unit of output continues its 1973-85 trend despite much lower energy prices, industrial energy demand will decline gradually between now and the end of the century unless output growth is 3 percent or greater. Alternatively, if the energy-output ratio of the average piece of energy-using equipment installed between now and 2000 is equal to the average energy-output ratio of all equipment in use in 1985, end-use energy by industry will grow at the same rate as real output; if real output growth is 2.5 percent, end-use energy demand will grow at 2.5 percent as well.

The two extrapolations on the top of Figure 3 provide additional benchmarks. First, if the energy-output ratio returns to its 1973 level (and real output grows at 2.5 percent), then end-use energy demand would grow at 4.8 percent per year. This is a projection that is consistent with prices returning permanently to their pre-1973 level and an assumption of full symmetry of the response of energy demand to lower prices with respect to its response to higher prices. In other words, this trend would result if prices return to their pre-1973 level for a long period of time and all technology and product mix decisions revert to those made in that year. Finally, the top line shows that if the economy were able to achieve its old long run potential growth rate, if there were full symmetry in price responsiveness and if prices fell to their pre-1973 level, then a 6.9 percent annual growth rate in end-use energy demand would result. To a significant degree, the analysis of industrial energy use centers on determining which of these historical trend extrapolations will prevail in the future.

Although the aggregate trends shown in Figure 3 are interesting, differential trends in the use of the individual energy fuels--oil, gas, coal, and electricity--can lead to some distortion in their interpretation. Part of the reduction in energy use over time represents shifts from lower to higher valued fuels like shifts from coal to oil and gas, or oil and gas to electricity. Higher valued fuels have a higher value because they are worth more in producing products that consumers value; if they were not worth more in production, no one would pay a higher price for them. One solution to this problem is the use of economic indices for energy prices and quantities, where the quantity of each fuel is weighted by its relative value in computing an adjusted aggregate quantity measure. Despite its theoretical attractiveness, results derived using this method can be difficult to grasp. Furthermore, since the most important trend to capture in analyzing industrial energy use is the trend from fossil fuel to electricity use, trends in these two types of fuels can be examined separately as a compromise between straight Btu aggregation and economic indexation.

Figures 4 and 5 repeat the framework developed in Figure 3 for fossil fuel and electricity use, respectively. Fossil fuel use grew at 2.8 percent from 1960 to 1973, implying a decline in the fossil fuel-output ratio of .8 percent per year. From 1973 to 1985, fossil fuel use declined at an average rate of 2.2 percent per year, implying a 3.6 percent per year reduction in the fossil fuel to output ratio. These trends are similar to, but more pronounced than, the total end-use energy demand trends.

The historical trend in electricity use departs significantly from the total energy and fossil fuel use trends. As shown in Figure 5, electricity demand grew at 5.9 percent from 1960 to 1973, implying an increase of over 2.0 percent per year in the electricity-output ratio. And from 1973 to 1985, electricity demand grew by an average of 1.7 percent per year,

Figure 4: Industrial Fossil Fuel Use Trends

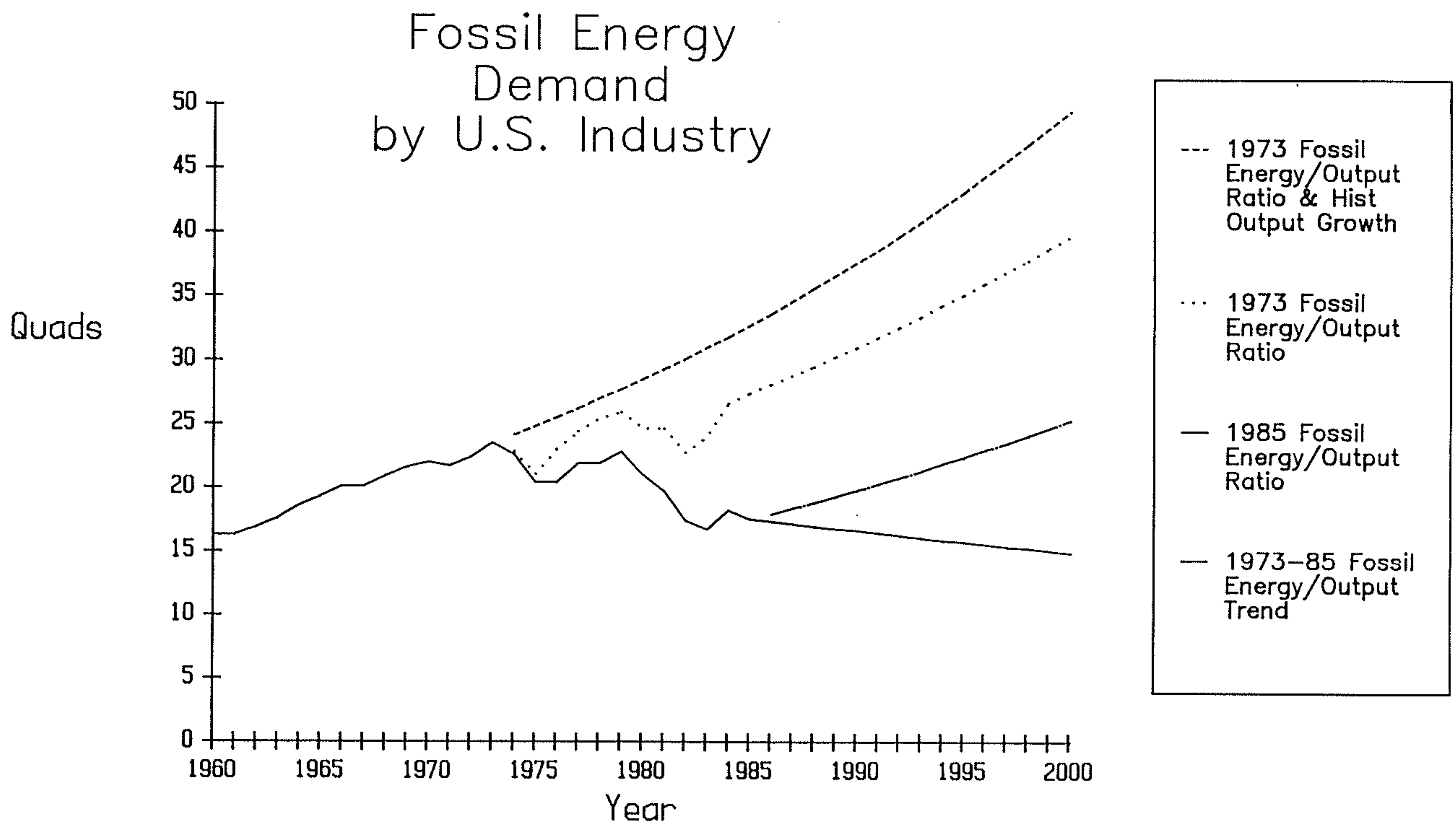
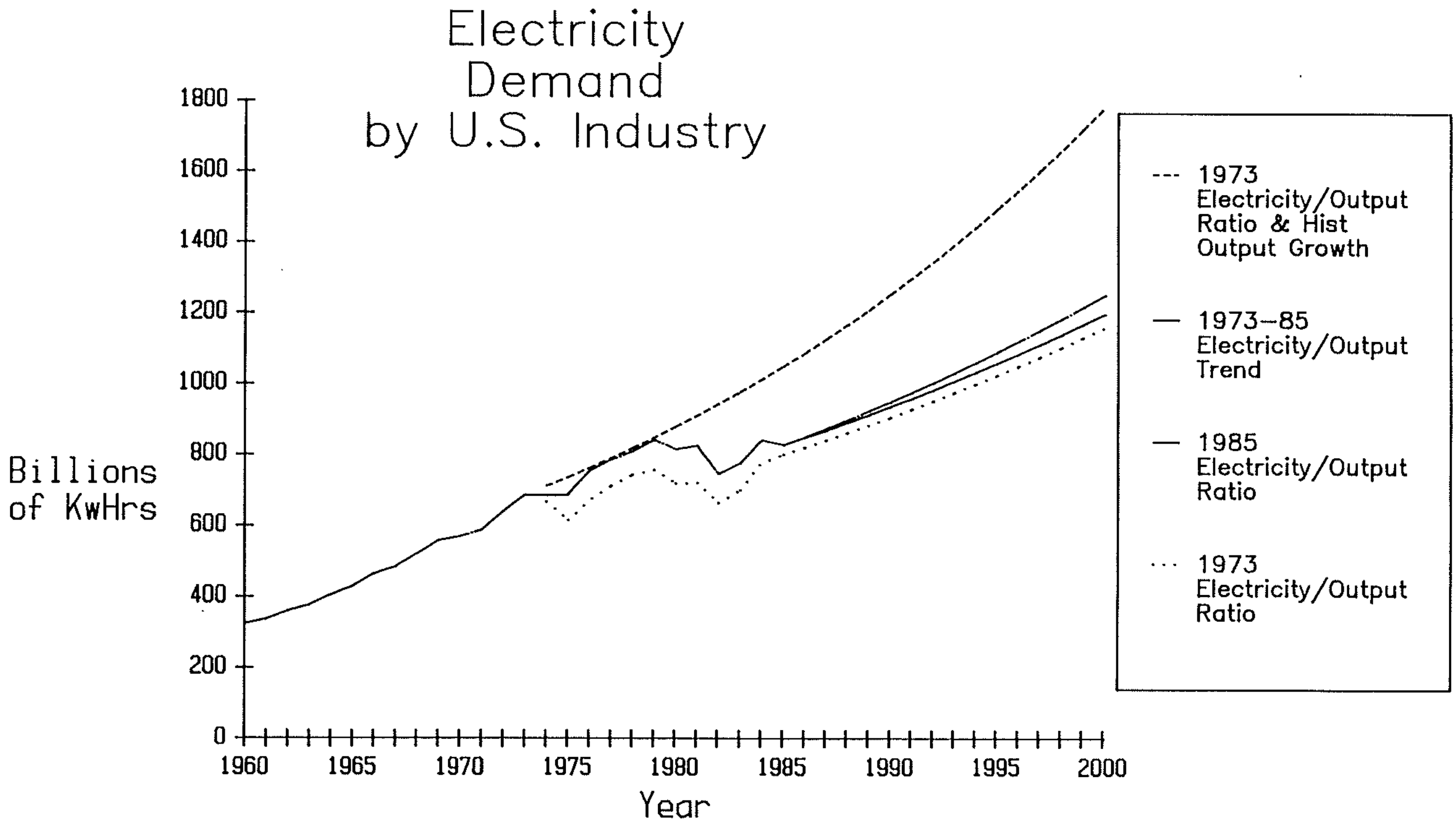


Figure 5: Industrial Electricity Use Trends



implying a .3 percent per year increase in the electricity-output ratio. A comparison of the historical trends in Figure 4 for fossil fuels with that in Figure 5 for electricity reflects the steady increase in the market share of electricity in total energy use that has taken place over both the pre- and post- embargo periods. This comparison suggests that future trends in energy use can be usefully disaggregated into trends in electric and nonelectric energy consumption.

4. THE EMF 8 MODELS

The 6 models included in the study were: the Wharton Annual model; the Industrial Sector Technology Use Model - 2 (ISTUM2) developed by Energy and Environmental Analysis, Inc. (EEA); the AES/ISTUM1 model maintained by Applied Energy Services, Inc.; the Purchased Heat and Power (PURHAPS) model developed by the Energy Information Administration; the Oak Ridge Industrial Model (ORIM); and the INFORUM model developed at the University of Maryland.

Each of these models has been refined and enhanced over a number of years and by now includes elements of all three approaches to energy demand modeling. Each has a specific methodology at its foundation. PURHAPS relies dominantly on econometric concepts and data-estimation techniques; ISTUM2 and AES/ISTUM1 on the process analysis methodology; ORIM combines the econometric and process analysis approaches; and Wharton and INFORUM rely on input-output analysis, with econometric estimation of values for parameters that reflect the adjustment of input-output coefficients, the composition of final demand, and the adjustment of the level of final demand to changes in the prices of inputs.

5. SCENARIO ASSUMPTIONS

A standard set of assumptions for key input variables defined the Reference case. These assumptions were input to as many of the models included in the study as possible, providing the degree of standardization necessary for comparison of model results. This standardization permitted the projections of industrial energy demand produced by a variety of models to be analyzed with respect to one another. In addition, an individual model's projections may be compared across different scenarios.

The input assumptions for world oil price in the Reference case are consistent with the reference projections of the EIA 1984 Annual Energy Outlook through 1995, and crude oil price growth rates from the base case projections of the National Energy Policy Plan from 1995-2000. The world oil price follows the EIA reference projection through 1995 and the growth rate of the NEPP crude price projections from 1995 to 2010. In this case, refiner crude oil acquisition costs, in inflation-adjusted terms, Alternative scenarios were specified to represent higher and lower world oil prices, higher and lower economic growth, lower natural gas prices, lower capital costs, an international oil price shock, higher electricity prices, lower coal prices, and a large decrease in the price of all energy fuels.

In the Low Prices Scenario all energy prices were reduced with respect to the reference case; oil and gas prices are reduced 30 percent, coal prices 20 percent, and electricity prices 10 percent from 1990 on. Between 1984 and 1990 prices ramp from Reference levels to the Low Price levels. In this scenario refiner crude acquisition costs decline to about $19 a barrel in 1990 in inflation-adjusted terms, and then increase at 3.6

percent per annum from 1990 to 2010. This trajectory implies about a 1.5 percent annual growth rate in inflation-adjusted crude acquisition costs over the study's 1984-2010 time horizon.

The Low Prices trajectory seemed quite low when it was initially proposed (in May 1985), but the oil price collapse of February 1986 actually resulted in prices 25 percent or more below those postulated in this scenario. By mid-1987 prices has rebounded to about the levels projected in the low prices scenario. By the conclusion of the study the low price scenario seemed closer to the consensus view of future energy price so it is the only one considered here. The results described here turn out not to be terribly sensitive to alternative assumptions regarding fuel prices and economic growth rates.

In Figure 6, the model projections of total industrial energy demand for the Low Energy Prices Scenario are superimposed on the historical trends framework developed in Figure 3. The model projections include: (1) fuel used for heat and power in manufacturing; (2) fuel used in agriculture, construction and mining; and (3) feedstocks. The model projections all show greater energy demand growth than would result from an extrapolation of the 1973-85 trend in the energy-output ratio, but less than the assumed rate of output growth. Industrial energy demand is projected to grow at between 1.0 and 2.1 percent per year, implying a .5 to 1.6 percent per year decline in total energy demand per unit of output.

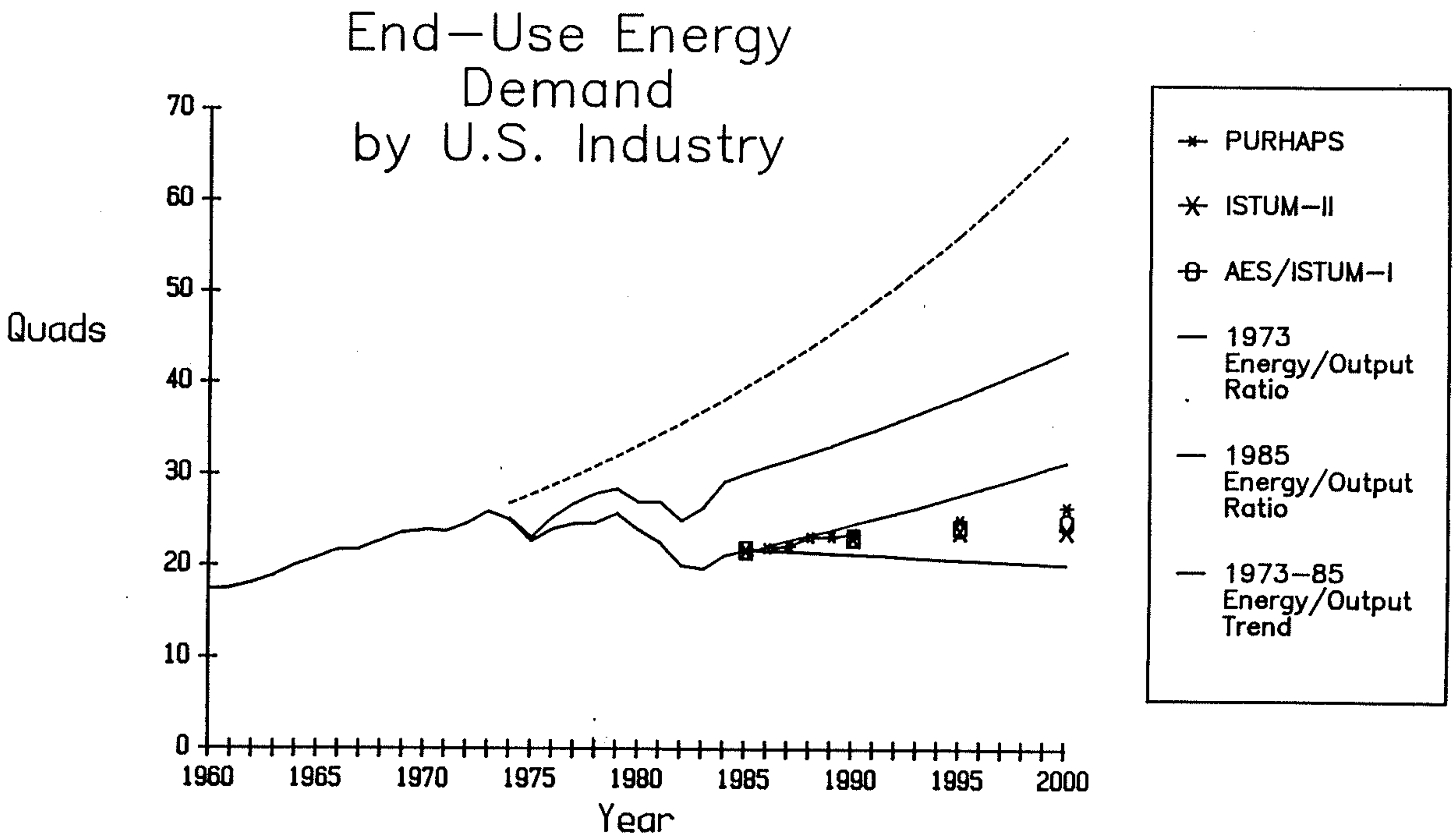


Figure 6: Model Projections of Energy Use by U.S. Industry

Total fossil fuel and electricity demand projections for the Low Energy Prices Scenario are put in historical perspective in Figures 7 and 8, respectively. Fossil fuel demand by industry is projected to grow at between .8 and 1.5 percent per year and electricity demand at 1.8 to 3.8 percent per year.

6. CONCLUSIONS

This study examined the use of analysis in the study of U.S. industrial energy demand trends. Several issues became central in the investigations of the working group: (1) the effect of changes in the structure of the U.S. economy on industrial energy demand; (2) the effect of trends in the technologies used to produce industrial products on energy use; (3) fuel choice by industrial energy consumers; (4) the quality of the existing public data on industrial energy use and recommendations for additional data collection efforts; and (5) the appropriate use of models by corporations in the energy producing and consuming industries.

A major part of the work of the working group was the specification of inputs and interpretation of outputs for eleven scenarios that were examined with a number of alternative models of industrial energy use. This work was supplemented with a review of the literature on industrial energy demand analysis, with a particular focus on sectoral shift and data quality studies.

Several conclusions emerged from the deliberations of the working group. Other things equal, lower energy prices should result in more energy use per unit of output. Nonetheless, several trends towards less energy consumption per unit of industrial output will continue even if the

Figure 7: Model Projections of Fossil Fuel Use by U.S. Industry

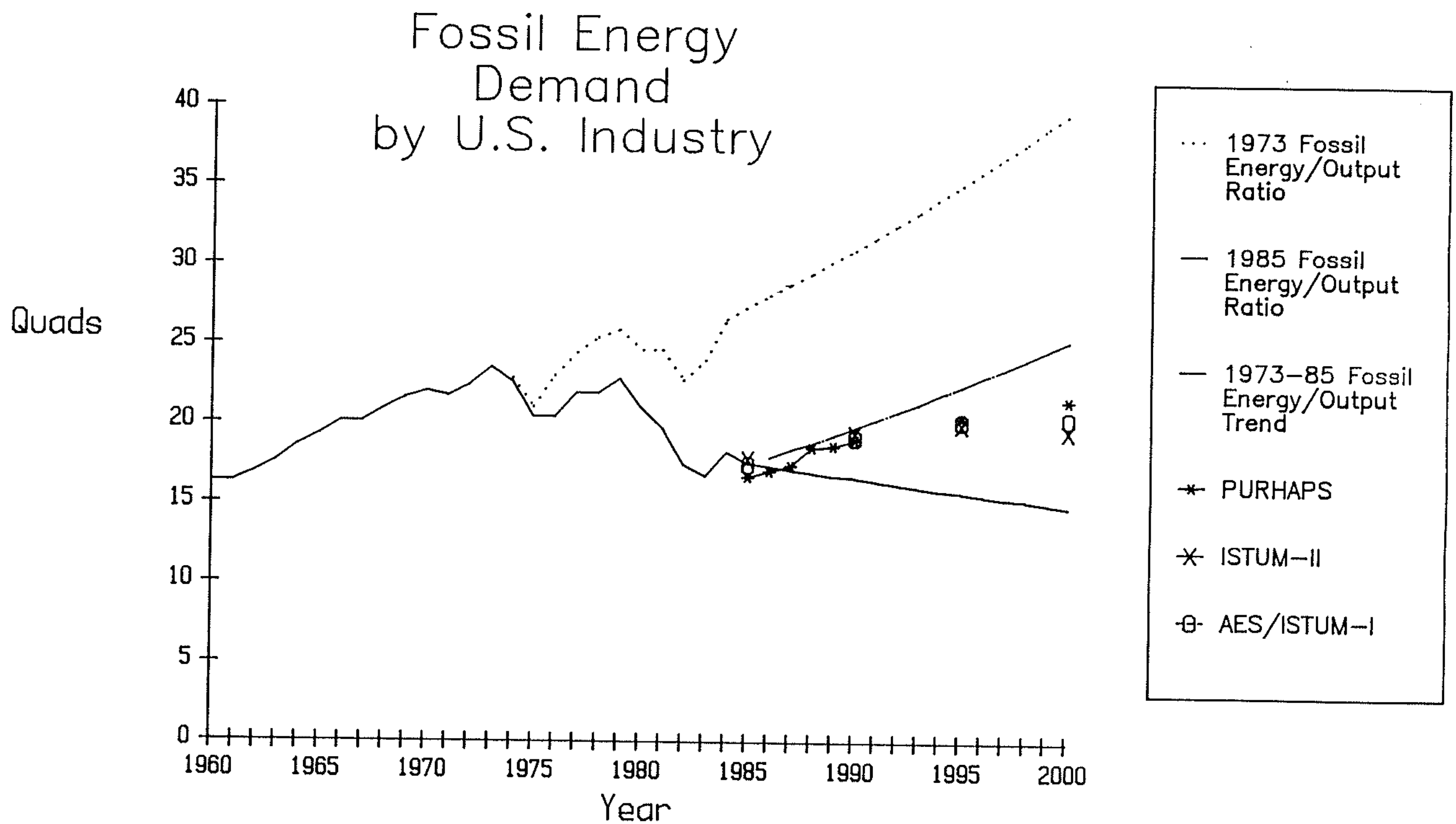
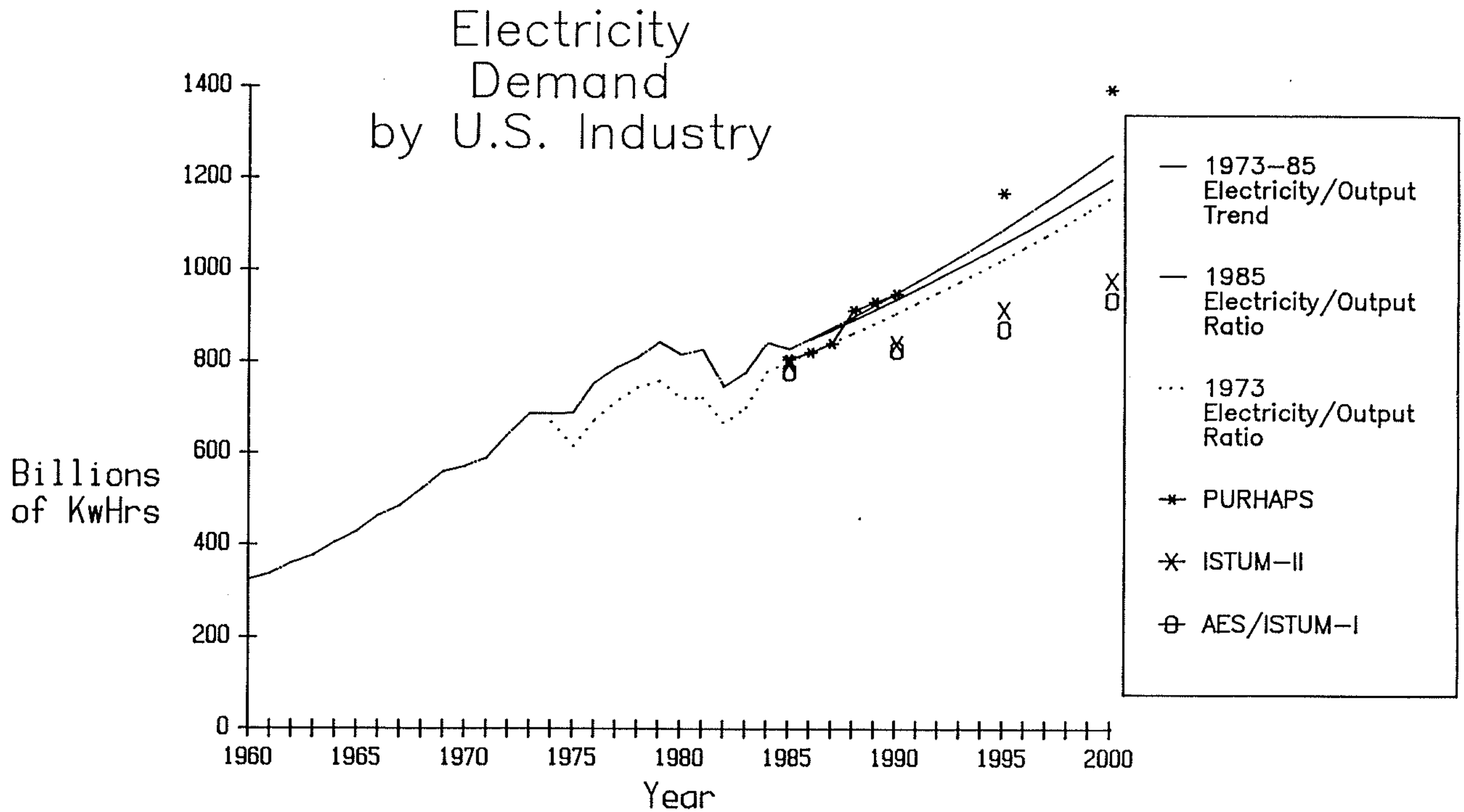


Figure 8: Model Projections of Electricity Use by U,S, Industry



much lower energy prices of 1986 continue into the future. The output of the U.S. economy will most likely continue to move towards producing a greater proportion of less energy-intensive products. In addition, many of the newer technologies being introduced to produce energy intensive products employ less inputs of all types, including energy.

Despite the gradual reduction in the intensity of energy use by U.S. industry, the long-run trends towards increased market share of electricity in total energy consumption is likely to continue. Some of the models project increases in electricity use per unit of output while others project decreases; even in the latter, though, the electricity-output ratio is projected to decline less than the ratio of fossil fuel use to output. On balance, the new technologies being introduced to produce energy intensive products are more likely to be based on electricity than upon alternative fuels, and the new products being introduced are somewhat more heavily dependent on electricity in their manufacture.

The competition between electricity and fossil fuels is relatively long-run in nature, owing to the embedded nature of energy use in relatively expensive capital equipment. The installation of large numbers of dual-fired boilers and the continued volatility of oil and gas prices have focused great attention on shorter-term fuel switching between oil and natural gas. There was great variability in the model results on this issue. The working group also was of the opinion that lack of good data makes any projection of the short-term fuel switching response to changes in the relative prices of those two fuels quite difficult.