ENERGY: A NATIONAL ISSUE

by

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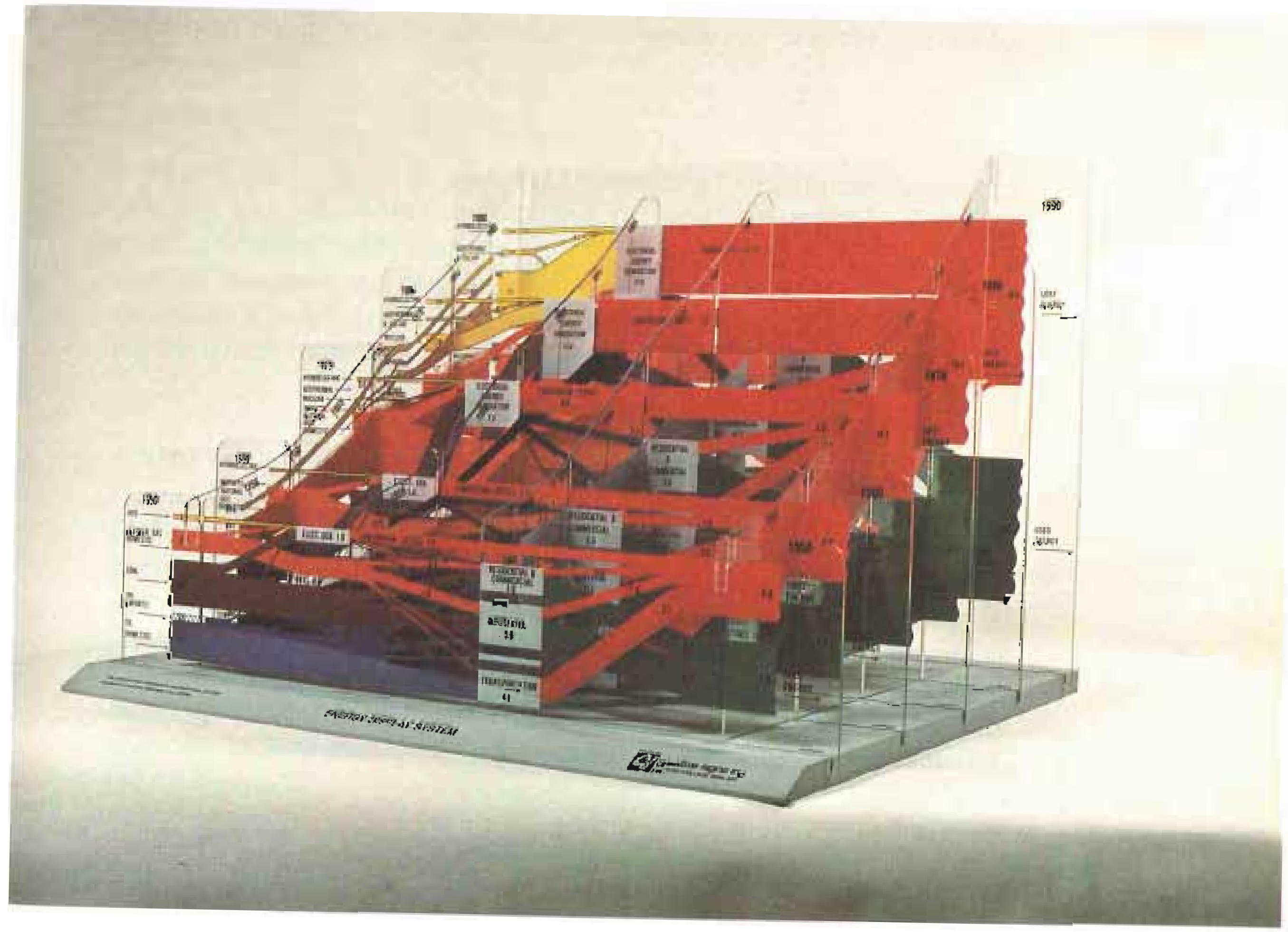


THE ENERGY DISPLAY SYSTEM

PREFACE

Energy: A National Issue is being published in an effort to convey to the American people a fundamental understanding of our energy problem. It is our hope that, armed with such an understanding, we will be able to make the difficult decisions which lie ahead and do so quickly. We are merely describing this problem; we have tried to avoid advocating any specific course of action. We believe that a well informed public who understands the issues can best make its own decisions.

In designing this book, care has been taken to maximize the ease of reading and of understanding the material presented. For this reason, we frequently suggest specific Foldout charts (located at the rear of the book) be used in conjunction with the text. To further assist the reader, we have provided in the last section a glossary of terms which may be unfamiliar.

This book updates the earlier work of Mr. Jack Bridges, entitled *Understanding the National Energy Dilemma*. That publication first unveiled the three-dimensional Energy Display System describing our nation's energy situation. The earlier work was developed by Mr. Bridges while a member of the staff to The Joint Committee on Atomic Energy, with the assistance of the Lawrence Livermore Laboratory. Subsequently, the book was published by the Center for Strategic and International Studies where Mr. Bridges was the Director of National Energy Programs, and received wide distribution.

We at CSIS still believe that the display system presented in that earlier work has been the most effective method yet devised to describe our nation's energy problem. As such, it is important that the earlier work be updated and presented to the American public in light of our experience since the Fall of 1973.

The author gratefully acknowledges the contribution made by Jack Bridges in his original publication *Understanding the National Energy Dilemma*. Much of the historical information used in that publication has been incorporated in this book. In addition, the basic three-dimensional concept of his earlier work has obviously been reemployed.

In addition to the contributions mentioned above, the author would like to acknowledge the contribution of Mark Meyer, who prepared the initial draft of parts of the text and chased down much of the elusive data used in the manuscript. Other contributors included Lyn Bickel, Abigail Bridges and John Mosca, who assisted with research, data and editing. Their efforts were most helpful.

Finally, the author acknowledges the contribution of CSIS, whose continued interest in calling attention to national problems and needs has encouraged and fostered work on this publication.

I. INTRODUCTION

A few years ago the U.S. public became acutely aware that all was not well with its energy system. This point was dramatically driven home by the Arab oil boycott, long gasoline lines, and the "energy crisis." Today our concern over the energy crisis is rapidly sinking from our national consciousness and the majority of us have all but abandoned efforts aimed towards solving this serious dilemma. But the basic situation has changed very little, and the opening paragraph of *Understanding the National Energy Dilemma* (1973) bears repeating.

> "The United States with 6% of the world's population is now using about 35% of the planet's energy and mineral production. The average American uses as much energy in just a few days as half of the world's people on an individual basis consume in one year. This nation has literally been developed without any significant restrictions due to the lack of natural resources. However, we now see ever increasing indications of the fact that the United States cannot long maintain the growth rate of recent years in our energy consumption without major changes in our energy supply patterns."

The persistence of this problem and the complexity of our energy system have made it imperative that a concise communications system be developed so that the public, industry, the academic community, and various levels of government can rapidly grasp the differing aspects of this energy dilemma. One excellent communications technique is the Energy Display System originally designed in 1973 for the Joint Committee on Atomic Energy; this display describes our energy system and the impact of various options that exist for this nation in dealing with our energy dilemma.

This updating of *Understanding the National Energy Dilemma* is made with the hindsight of the embargo, the energy crisis, and the economic woes of recent years. These updated projections provide further indications that our energy problems will be long-run in nature and will be resolved neither quickly nor easily.

The need to understand our energy position is more important now than ever. Unfortunately, *Energy: A National Issue* is being prepared in a time when the American public feels the energy crisis has "gone away." It is hoped this book will reawaken us to the fact that the energy crisis is still with us and is worsening through our inaction.

II. THE ENERGY DISPLAY SYSTEM

The Energy Display System was designed and has been used to help people from all backgrounds understand their energy system — past, present, and future. The charts and graphs contain information that is available to the public, and the reader could construct charts for any year he wished.[1] The years shown in this book were chosen to give the reader a broad view of the U.S. energy system.

At the beginning of this book is a photograph of one model of the Energy Display System. This model was made by printing upon plexiglas sheets a series of charts which show the U.S. energy flow pattern for five different years (Foldouts A through F of this book) and then intersecting these at right angles with the cross plots (Foldouts H through K) also printed upon plexiglas sheets. The cross plots show certain information — our energy efficiency, who uses our energy, the sources of our energy, and the different energy conversion processes we use — over a 40 year time span. These projections were obtained from a host of published sources; an explanation of the methodology used to develop the projections is contained in Appendix B.

The most effective way of using this book is for the reader to open the designated Foldout when suggested and then follow its description in the text. The various Foldouts are located in the rear of this publication.

The energy unit used in the Energy Display System is that of a million barrels per day of oil equivalent (MB/DOE). In part, MB/DOE was chosen because a barrel is easier to visualize than, say, a kilowatt or a BTU. In addition, this standard unit provides a common denominator which permits us to appreciate the relative importance of various fuels. Finally, oil is one of the key U.S. fuels, and imported oil is the major factor in our national energy dilemma.

To convert other fuels to MB/DOE, calculate the energy that would be produced from various energy forms and then convert those numbers into the number of barrels of crude oil that would have to be used in order to obtain the same amount of energy. In order to give the reader a better concept of the magnitude of the MB/DOE units, Table I lists several well-known items and expresses them in terms of MB/DOE.

Table I: Typical Oil Equivalents

Item	Energy Form	Million B/DOE
Texas	*Daily* oil production (1975)	3.3 and declining
Louisiana	*Daily* natural gas production (1974)	4.0 and declining
West Virginia	*Daily* coal production (1972)	1.4
Hoover Dam	*Daily* electricity capacity	0.02
U.S. Nuclear Power	*Daily* generated electricity (1975)	0.8
The U.S. in 1970	*Daily* wood consumption for fuel	0.4
Large Supertanker	Oil per load	1.5 (per voyage)
Los Angeles Area	*Daily* energy consumption (from all sources)	1.0
Average American Adult	*Daily* average calorie intake	0.00000002
The Sun	*Daily* total energy radiated (in all directions)	400,000,000,000,000

Total Energy Flow Pattern For 1960

In order to use the Energy Display System, the reader needs to first become familiar with an energy flow pattern for the United States during a period when the system was relatively simple. The total energy flow pattern for the year 1960 will be used as our basic example. *(Open Foldout B – skipping for now Foldout A.)* Foldout B is the chart of our total energy system for 1960 — remember, this is history. All information in the Foldouts is shown to the same scale and has been converted to the MB/DOE unit previously described.

Supply/Demand

Oil

On the left-hand side of the chart, under the arrow marked **Supply/Demand,** we see each type of fuel used in 1960. Starting from the lower left corner of the chart, observe that the total U.S. oil supply in 1960 consisted of oil from domestic sources (7.8 MB/DOE), and oil from imports (1.9 MB/DOE). Under the arrow marked **Form of Use,** notice the small amount of oil (0.3 MB/DOE) shown to have been used in Electrical Energy Generation, and how the United States exported 0.2 MB/DOE in oil. Under the arrow marked **End Uses,** notice how we utilized a considerable amount of oil (2.0 MB/DOE) in Residential and Commercial (about 75% for dwelling units and the remainder for offices, shopping centers, schools, etc.), considerably less (1.3 MB/DOE) in Industrial (iron and steel, auto manufacturing, etc.), even less in Nonenergy (0.8 MB/DOE) uses (manufacture of fertilizers, petrochemicals, plastics, etc.), and we used the largest share of our oil (5.0 MB/DOE) in Transportation (autos, planes, trains, etc.).

Coal

Now, looking back to the left of the flow pattern under **Supply/Demand,** the reader will see that in 1960 total domestic coal production of 5.3 MB/DOE was less than oil or natural gas. More than half of the nation's electric energy in 1960 was generated by burning 2.0 MB/DOE of coal. Under **End Uses,** a relatively small amount (0.5 MB/DOE) was exported. A small amount of coal was used (primarily for heating purposes) in Residential and Commercial, and a trace was used in Transportation (we still had some coal-fired railroads operating in 1960). The largest single use of coal (2.3 MB/DOE) was Industrial, particularly in iron and steel production, and other heavy industries. Also note that we used some coal in Nonenergy.

Natural Gas

Now back to the left of the chart, the reader will notice that the country's total natural gas supply was composed of domestic sources (5.8 MB/DOE), and a trace (0.1 MB/DOE) of imports from Canada. Some natural gas (0.8 MB/DOE) was being used to produce electric energy. A great deal of natural gas (2.0 MB/DOE) was utilized in Residential and Commercial, and Industrial (2.8 MB/DOE) was the largest user of natural gas. In 1960, industry received more energy from natural gas than from coal. Some natural gas was used in Nonenergy, and a small amount of natural gas was used in Transportation — primarily to drive some of the pumps and compressors of the vast pipeline systems which exist in the U.S.

Hydroelectric

Back to the left of the chart, the reader can see that hydroelectric supplied 0.3 MB/DOE to the nation's energy supply in 1960. The United States had no significant production of energy from nuclear, geothermal, or other sources in the year 1960.

Form of Use

Now look under the arrow marked **Form of Use.** This region of the display shows the conversion of one type of energy into another. In 1960, the only significant conversion process was Electrical Energy Generation. For the year 1960, oil (0.3 MB/DOE), coal (2.0 MB/DOE), natural gas (0.8 MB/DOE), and hydroelectric (0.3 MB/DOE) were used to produce electricity.

A little less than half of the actual electricity generated was used by Residential and Commercial (0.5 MB/DOE), and slightly more (0.7 MB/DOE) was used by Industrial.[2]

In the process of burning fuel to produce electricity, we lost almost two-thirds of the total energy put into our electric generation system. This loss — shown as Conversion Losses in the display — should not be considered unusual. Any technology we have now or will develop in the future is subject to the laws of physics. In any conversion process, there is a penalty for energy change. Presently, in electrical energy generation the maximum conversion efficiency is about 40% (in conventional steam electric plants).

End Uses

The area under the arrow marked **End Uses** describes the composition and amount of energy demanded by each of four different sectors of the economy. Each of these sectors — Transportation, Nonenergy, Industrial, and Residential and Commercial — has its own peculiar fuel needs; the "mix" of fuel types used by each sector will depend in part on the nature of the sector, its technology, energy prices, and consumer preferences.

In 1960, the total mix for Transportation consisted of three fuels. Oil was the primary fuel, accounting for well over 90% of all energy input. Coal and natural gas provided fuel for the remaining transportation efforts.

The Nonenergy sector depended heavily on oil (0.8 MB/DOE), and, to a lesser extent, on coal (0.1 MB/DOE) and natural gas (0.2 MB/DOE).

Industrial use of energy was more diversified than the previous **End Use** sectors. Here natural gas (2.8 MB/DOE) and coal (2.0 MB/DOE) provided the bulk of energy while oil (1.2 MB/DOE) and electricity (0.7 MB/DOE) accounted for the remainder.

Finally, we have Residential and Commercial. In 1960, we find 80% of the demand was met by natural gas and oil, with the remaining needs being met by coal and electricity.

Many people are surprised to find that electrical energy makes such a small contribution to our Residential and Commercial energy needs; however, the largest single use of energy is in the heating of rooms and buildings — "space heating" — and this is for the most part provided by natural gas or oil furnaces.

Efficiency

Now examine the area under the arrow marked **Efficiency.** This is the efficiency with which each **End Use** converts the total energy it is supplied to useful work.[3] Note that the least efficient user was Transportation. This sector, with an input of mostly oil, lost or rejected over 75% (4.0 MB/DOE) of that energy input. Accordingly, only about 25% was actually converted to useful work moving our autos, trucks, trains, aircraft, and ships. This alarmingly low **Efficiency** is the penalty we pay to attain our mobility.

Industrial, with its total input of 7.1 MB/DOE, lost about 30%, but effectively utilized almost 70% of the oil, coal, natural gas, and electricity it was supplied.

Residential and Commercial took its total input (5.0 MB/DOE) and lost about 30% while utilizing nearly 70%.

Finally, if the reader will examine the overall efficiency of the system in 1960, he will notice that the total losses, or **Lost Energy**, were made up of the conversion losses (2.3 MB/DOE) from Electrical Energy Generation and the losses from Residential and Commercial, Industrial, and Transportation, for a total of 9.9 MB/DOE rejected. Our useful energy consisted of 3.5 MB/DOE in Residential and Commercial, 4.9 MB/DOE in Industrial, and 1.2 MB/DOE in Transportation. We actually lost, or perhaps it would be better to say we were unable to capture and put to use, about 51% (9.9 MB/DOE), and we were able to use slightly over 49% (9.6 MB/DOE) of the total energy consumed in this country during 1960.

Energy Flow Pattern For 1950

(Keep Foldout B extended and open Foldout A.) Foldout A is the chart of the total energy flow pattern of the United States in the year

1950. Notice that the physical size of the chart, measured vertically, indicates that the total energy consumption in the United States in 1950 had already grown to about 75% of what it would become in 1960.

A more detailed comparison of 1950 and 1960 indicates several changes in our pattern of energy consumption. Many of these changes are the result of the gradual altering of our way of life, or "life styles". The reader will notice that between 1950 and 1960, Electrical Energy Generation grew by almost 80%. This is, in part, the result of more people enjoying the benefits of electric power. From 1952 to 1960, the number of households wired for electricity grew by 22%. In addition, the number of electrical appliances in those homes grew. In 1952, air conditioners were present in only 1 in every 75 of the homes that had electricity; by 1960 this had grown to 1 in 7 in the homes that were wired; 1 in every 30 had clothes dryers in 1952, compared to 1 in every 5 for 1960. Televisions were found in 1 of every 2 homes with electricity in 1952 while by 1960, 9 out of every 10 of these homes enjoyed the benefits of television.[4]

Transportation also showed considerable change in the decade from 1950 to 1960. Whereas oil provided well over 90% of our fuel in 1960, it constituted less than 80% in 1950. Coal, which provided a sizeable amount of our transportation energy in 1950, had practically vanished in Transportation by 1960. This is evidence that not only were our ways of living changing, but also our ways of moving. While the number of automobiles in use grew by almost 60% between 1950 and 1960, the number of steam locomotives declined from almost 27,000 in 1950 to less than 400 in 1960.[5] For the most part, the coal-fired locomotives were replaced by oil-fueled diesel engines.

Moving back to the **Supply/Demand,** left side of the Foldouts, we can see the effects which our changing life styles had on energy production. Whereas the use of oil, natural gas, and hydroelectric power had increased in the decade between 1950 and 1960, use of coal actually dropped by more than 18%; Industrial use of coal declined by 20% while Residential and Commercial use dropped by almost two-thirds. As a matter of fact, between 1950 and 1960 Electrical Energy Generation was the only area where coal use increased.

Many of the reasons for this decrease in the use of coal stem from the advantages which other fuels offer. For most consumers, coal cannot compete with natural gas and oil in areas of cleanliness (coal-fired plants emit excessive amounts of flue-ash and other pollutants unless properly controlled), ease of handling, and transportability. Also, during this period oil and natural gas became economically competitive with coal. The point to be made here is simple yet very important: our energy consumption patterns reflect, to a large extent, the way we *wish* to live.

Energy Flow Pattern For 1970

(Close Foldouts A and B, open Foldout C.) Foldout C is the chart of the total energy flow pattern of the United States in the year 1970. The chart for 1970 is to the same scale as that of 1950 and 1960. Notice the overall growth of the energy factors. The reader need not go through as much detail for the year 1970 as he did for 1960, but there are certain major points of interest.

In the decade between 1960 and 1970 two things should be noted — first, it was the decade of a massive expansion in the use of natural gas (it nearly doubled), and second, the United States moved toward an even greater use of electricity. Coal use increased slightly over 40% — most of the increase going to generate this electric power — while oil use increased nearly 50%.

Notice that under the arrow labeled **Supply/Demand** nuclear and geothermal energy appear for the first time. Some have said that in 1970 the energy obtained from nuclear power was not even as much as the energy obtained from firewood. While this may at first seem humorous, it does provide an important insight as to the length of time it takes for a new technology to make a significant impact on a system as large as ours — the first nuclear power plant began operation in 1957.

Electrical energy more than doubled in the 1960-1970 period. This reflects the flood of appliances into Residential and Commercial. By 1970 almost all homes were electrified, air-conditioning became commonplace, color TVs, clothes dryers, and electric lawn mowers appeared, as did the all-electric home. For the first time in 1970 the use of electrical energy for Transportation was noteworthy.

It is also interesting to note the disappearance of coal in Transportation, the major decrease of coal in Residential and Commercial, and the significant use of natural gas and coal in Nonenergy for products such as fertilizer and plastics.

To the extreme right of Foldout C, the reader will notice that **Lost Energy** for 1970 was actually slightly less than **Used Energy**. The efficiency of our overall national energy system for the years 1970 and 1971 may well turn out to be the best for many decades. We had

not yet embarked upon our environmentally beneficial efforts to "clean up" the internal combustion engine, to clean up electric power production facilities, etc., with the resulting penalty to fuel consumption efficiency.

Energy Flow Pattern For 1975

(Close Foldout C and open Foldout D.) Foldout D shows our total energy system as it looked in 1975. It is important to look more closely at our energy system in the light of two very significant events — the Arab oil embargo of 1973-74 and the sharp business recession of 1974-75.

Comparing the 1975 energy flow chart with that for 1970 it is apparent that the rate of growth during this interval is considerably lower than in prior years (in fact, energy demand actually declined slightly during 1974 and 1975.) This decline reflects several forces such as the economic downturn, higher fuel prices, and conservation efforts.

While demand was held somewhat in check, domestic production of oil and natural gas declined mainly because of dwindling resources. In fact, both oil and natural gas experienced decreases of more than one million barrels per day from the 1970 levels. This decreasing supply resulted in a rapid increase in oil imports as well as some growth in our imports of natural gas.

The mix of fuels put into Electrical Energy Generation shows an interesting shift. In 1975, we were using considerably more oil and nuclear fuel in our generating plants; coal and hydroelectric increased slightly while the use of natural gas declined. This was the result of a conscious effort under government direction to reduce the use of natural gas as an electric generating fuel; again, this effort was a reaction to our dwindling natural gas reserves.

In examining **End Uses** of energy in 1975, it is easy to see that Industrial use of energy declined (natural gas was most affected, while the use of oil and electrical energy increased slightly). The use of energy in Transportation and Residential and Commercial showed some growth over the 1970 levels.

Industry took the brunt of the 1974-75 recession while our use of energy in Transportation grew, increasing our dependence on oil which we could no longer easily find in our own back yards. Despite the severe lessons of the Arab oil embargo and the higher oil prices, by the end of 1975 we found ourselves with an energy system more dependent than ever on imported oil.

Projected Energy Flow Pattern For 1980

(Close Foldout D.) Up until now, we have been looking at our energy history. Nothing will alter the energy use patterns for 1950, 1960, 1970, or 1975; our energy future, however, is a different matter. The state of our technology and the availability of different fuels can be influenced by our conscious decisions concerning our future needs. It is important to remember, however, that in an energy system as large as ours, change will not come quickly. The American public will have to expend much time and effort if it decides to reverse the trends of the past 30 or more years. As creatures of habit, we tend to alter our behavior slowly and often only after change is perceived as necessary (consider the Surgeon General's report on smoking issued years ago).

The projection of our energy flow for 1980 is a composite of several widely used forecasts made by government agencies, industry, and private institutions. Some may label these forecasts optimistic in terms of our willingness and ability to change; still others may label them pessimistic in overestimating the time needed for such changes to occur. Only history will verify the forecasts, but it is important to note that they do represent a significant departure from past trends, and as such, they present challenges to us as users of energy.

(Open Foldout E.) Viewing the 1980 display, it is immediately evident that the rate of growth in energy use between 1950 and 1970 is considerably higher than between 1970 and 1980. (This is partially due to the fact that between 1970 and 1980 we as a nation are expected to make a conscious effort to reduce our energy consumption.) Whereas energy use increased at an annual rate of 3.5% between 1950 and 1970, between 1970 and 1980 energy use is projected to increase at an annual rate of 2.5%. (Much of this growth has already occurred during the 1970 to 1975 period.)

Moving to the area under the arrow marked **Supply/Demand,** it is projected that use of all fuels may increase for 1980. Oil use is projected to increase by 28% with the bulk of this increase supplied through imports. As a matter of fact, by 1980 we would be more dependent on foreign oil than we were in 1970. Coal use is projected to increase by 27% in this decade while natural gas use would increase

only slightly. Comparing 1970 and 1980 again, the reader will notice that domestic natural gas production is projected to decline by almost 3% while natural gas imports may increase by 300%. Nuclear energy is projected to increase 28 times over 1970, yet in 1980 it still only comprises 7% of our total energy input. Less significant in terms of energy input is geothermal and solar energy — in 1980 these may add 0.7% to our supplies. Hydroelectric power is expected to increase by 50% over 1970.

Moving to the area under the arrow marked **Form of Use,** a trend familiar to us even now is more evident in 1980 — it is predicted that Electrical Energy Generation will increase by about 70% in this decade. Coal may still provide the bulk of the supply, but nuclear energy would replace natural gas as the second largest source.

It is in this decade that we first see some of the new conversion processes which our technology will make available. Coal-Gas (produced by converting coal to synthetic natural gas, a process known as "coal gasification"), Oil-Gas (converting oil to synthetic gas), and Coal-Oil (converting coal to synthetic oil, called coal liquefaction), all would be used to help meet our energy needs. These processes, however, will not be our energy salvation in 1980. As the display indicates, they would contribute very little toward our energy supply. All three processes combined would contribute only about 1% of our energy needs. As with electricity, there is also a conversion penalty to pay. One third of the fuel potential of the inputs is estimated to be lost in these conversion processes.

Moving to the right of the display, we find several changes in **End Use.** In 1980, Transportation would use 25% more energy than in 1970; it would still depend on oil for over 95% of its needs — not significantly different from 1970. There are several reasons for this lack of change. It will take a considerable amount of time to develop modes of transportation that do *not* depend on liquid fossil fuels. Also, if our past experience with automobile replacement is any indication of what can be expected between now and 1980, then three out of every four automobiles that are on the road today will still be on the road in 1980.[6] Change, save for in a true crisis situation, will occur slowly in a system as large as ours.

Nonenergy shows the most growth of the **End Uses** during this decade. Our increasing use of plastics, fertilizers, and petrochemicals will lead to an increase in this sector of almost 50% between 1970 and 1980.

Interestingly enough, Industrial is projected to grow by only 9% from 1970 to 1980. This 9% energy increase in Industrial is extremely low — perhaps unrealistically low. From 1960 to 1970 Industrial energy use increased by almost 40%. In the decade previous to that (1950 to 1960), the energy increase was almost 27%. Later, we will examine the implications of this low growth rate in greater detail, but generally, it is assumed that the higher fuel and energy costs will stimulate effective conservation efforts that will reduce waste and loss without seriously disrupting industrial activity.

Residential and Commercial is predicted to grow by 36% from 1970 to 1980 with the use of coal disappearing and the use of oil remaining constant. The increase in this sector is provided by electricity, which doubles, and natural gas.

Looking at the area under the arrow marked **Efficiency,** we see that unlike 1970, our **Used Energy** will be less than our **Lost Energy** in 1980. By 1980 we will be using only 47% of our energy efficiency. The bulk of the lost energy (almost 75%) comes from Transportation and Electrical Energy Generation. Using today's technology, and with a greater emphasis on electrical energy, we would increase the relative inefficiency of our total energy system.

Projected Energy Flow Pattern For 1990

(Close Foldout E, open Foldout F.) Foldout F projects our energy system as it might appear in 1990. This may seem a long way off, and many things may change, but 1990 is less than 15 years away and much of what is present today will still be with us then. As with 1980, we do have a choice about our 1990 energy system; however, our options are and will be constrained by our past and present decisions which can be made either consciously or by default.

Looking under the arrow labeled **Supply/Demand,** we could use 24% more fuel in 1990 than was projected for 1980 — almost 60% more than in 1970. This is also the decade when the limited capacity of our domestic oil and natural gas supplies becomes most evident.

From 1980 through 1990, the demand for oil is projected to grow slowly while domestic oil production is expected to decline slightly. This drop comes even with the Alaskan Pipeline and the projected oil shale production adding to our domestic supply. Therefore, imports would increase, making us dependent upon foreign sources for nearly half of our oil in 1990.

The demand for coal is estimated to be 29% above 1980 levels. Electrical Energy Generation would still be the major market for coal

in 1990. Interestingly, however, direct use of coal in industry (3.0 MB/DOE) is projected to be the highest in the 40 year period of our study; Coal-Gas and Coal-Oil show a threefold increase over 1980, but this still constitutes only a small part of the coal used.

Domestic natural gas use would continue its downward trend, declining by 15% between 1980 and 1990. This is due to our limited supply, not a decreasing demand for natural gas. Even though natural gas imports would be up 17%, total natural gas use would fall by 12%.

Almost all projections expect significant increases in nuclear energy by 1990; those more optimistic predict a 250% increase for nuclear power over 1980. This is one area where our action or lack of it will prove to be very important. It is technically quite possible to accomplish this increase if we choose, but we must first make the conscious decision to do so. Due to the long time involved in the planning and the construction of nuclear plants (8 to 10 years), if we do not act by 1980, we will have already eliminated nuclear power as a major energy option from our 1990 energy system.

The last two energy inputs exhibit very dissimilar rates of growth. Geothermal and solar energy are projected to grow by 167% over 1980 as their technology emerges from its infancy. But for hydroelectric it is predicted that by 1980 most major sites will be used; therefore, no additional growth in this area is forecast for 1990.

Continuing our analysis of the 1990 system, consider the area under the arrow marked **Form of Use.** Electrical Energy Generation is projected to continue to grow. In 1990, it is projected to be half again as large as 1980 levels, or one-and-one-half times larger than 1970. By 1990, nuclear energy would supply over half the input for electrical generation with coal being second. Other conversion processes (coal gasification, etc.) are projected to increase in 1990 to reach the equivalent of 1.7 MB/DOE of synthetic natural gas production and 0.8 MB/DOE of synthetic crude oil.

Considering the 1990 **End Uses,** you will notice that Transportation is still highly dependent on oil and that Nonenergy continues its rapid growth. As it is assumed that most of the easy and less costly conservation measures would already have been taken by 1980, Industrial use of energy would start increasing. In 1990 the Industrial fuel mix does show a trend which will likely become stronger — the use of both natural gas and oil declining with the direct use of coal and electrical energy becoming far more important. By 1990, new household formations (which were at a high rate during the 1970's and early 1980's as a consequence of the "baby boom" of the late

1940's and 1950's) are expected to drop to lower levels; therefore, a relatively low increase in the fuel use for Residential and Commercial is projected.

Completing our examination of 1990, you will note that we would still lose more energy (54%) than we would use (46%). Our energy **Efficiency** in 1990 would reflect an increasing reliance on Electrical Energy Generation. (Close Foldout F.)

This completes our picture of the energy system at six points in time. You have seen how our ways of living have affected our energy **Supply/Demand, Form of Use, End Use** sectors, and **Efficiency.** In the next section, we will take a closer look at the way each of these behaves over time.

III. ENERGY TRENDS

Now if the reader would visualize intersecting the energy flow patterns for each year at right angles in the four areas indicated under the arrows on Foldouts A through F, one could construct graphs showing the behavior of various segments of our energy system over a 40 year time span. We have selected four areas for closer examination — **Supply/Demand, Form of Use, End Use,** and **Efficiency** — over the years 1950 through 1990.

(Open Foldout G.) This is a sketch of how the cross plots are constructed. Foldout G shows how the **Efficiency** cross plot would be prepared.

Cross Plot: Efficiency

(Close Foldout G, open Foldout H.) This is the **Efficiency** cross plot resulting from the construction process shown on Foldout G.[7] The information presented on these various cross plots can be converted to other forms. For example, the MB/DOE units shown on the **Efficiency** cross plot could be converted to the percentages presented in Table II.

Table II: Energy Use Efficiency

Year	Percentage of Used Energy	Percentage of Lost Energy
1950	54	46
1960	49	51
1970	51	49
1980	47	53
1990	46	54

More troublesome than the fact that we never really use much more than half of our energy efficiently is our deteriorating energy efficiency in the future. It would appear that if we could only use the energy we have more efficiently, then we would not have to worry about an energy crisis. Why not just concentrate on improving energy efficiency?

There are several factors which prevent efforts to improve energy efficiency from being the one and only answer to our energy problems. We must realize that any policies we may decide to undertake will be limited by the physical reality of our world. To date, and probably for many years in the future, generation of electrical power will be a process of converting heat energy into electrical energy. This conversion necessarily involves energy waste, but it is a waste that we have found necessary for the convenience and the peculiar characteristics of electrical power. (It would be difficult to light our homes by burning coal in our basements or backyards.)

This brings us to the second problem concerning energy efficiency. Most of our industrial and residential buildings were constructed before the events of recent years publicized the energy problem. These buildings, machinery, generating plants, etc., were constructed in a time of cheap and plentiful fuel; people did not have to worry then about sacrificing some energy efficiency. Although most of us are now aware of the need for energy efficiency, we replace only about 1% of our housing units per year; therefore, the systems which are already constructed will continue to influence our energy efficiency far in the future.

It is clear that efficient use of our energy is a major problem in our system. It is also clear that there exists much potential for improvement. The problem is basically one of time. We need time to develop new energy-efficient technology. We need time to bring this technology to widespread use. Improving our efficiency is going to require much more of a commitment from us now than it has in the past — much more than just putting up a few more storm windows, although that is a beginning.

Cross Plot: End Uses

(Close Foldout H and open Foldout I.) This is a cross plot intersecting all of the annual energy flow patterns under the arrows marked **End Uses.** This one shows the growth of energy uses in the various sectors of our national economy from 1950 to 1990.

Examining this cross plot you will notice that there is a marked change in the rate of growth of our energy use beginning about 1973. From 1950 to 1973, our energy use grew 3.4% annually. It is projected, however, that this growth rate will drop to 2.3% annually in the period 1973 to 1990. This drop in growth rate is clearly desirable if we consider only the consumption of our scarce resources, but are there other effects which may not be so desirable?

Behind the forecasted change in energy growth rates is the assumption that we can, to some degree, separate or "decouple" energy growth from economic growth. Whether we can actually achieve these levels of change without unacceptable economic penalties remains to be seen. Hopefully we can.

Cross Plot: Form of Use

(Close Foldout I and open Foldout J.) This cross plot is constructed so the reader can see changes in **Form of Use** as the energy is made available to the final consumer. The amount of coal reaching the final consumer is quite small because most coal is used in electrical generation and, therefore, is not shown as being used directly by the consumer.

Quite surprisingly for some, our energy system is based for the most part on liquid and gaseous fuels. Electrical energy, which we all use every day, is a very small proportion of the total energy used by the final consumer. *(Close Foldout J.)*

Cross Plot: Supply/Demand

(Open Foldout K.) This is the **Supply/Demand** cross plot drawn by intersecting all of the annual energy flow patterns under the arrows marked **Supply/Demand.** In the resulting chart, we have shaded the patterns for imported oil and imported natural gas so that the reader can easily distinguish imports from our domestic sources.

You will notice that our domestic oil and natural gas production will be hard-pressed to match ever again the production of the early 1970's — even with the Alaskan North Slope and advanced drilling and recovery techniques.

If the supply of one fuel is depleted, restricted, or hindered, then pressure is exerted on the remaining fuels to provide an increasing contribution to our energy systems. Limited supplies of natural gas have certainly led to increased pressure on other fuels, primarily oil. If plans for nuclear electrical plants are cancelled, there would be additional pressure on other fossil fuels (probably coal), and if coal meets some barriers, the fuel demand will have to be met elsewhere. *(Close Foldout K.)*

Hopefully it is clear to all that we will be forced to make some very hard decisions concerning our energy systems. One of the more difficult of these decisions involves environmental safeguards. Much of what has been proposed to help solve our energy dilemma involves some degree of environmental hazard. There is no established rule for how this environmental/energy conflict should be handled, but somehow we must strike a balance. Most energy solutions will have an environmental cost while many environmental proposals will have an associated energy penalty. An awareness of the costs of the various options will enable us to choose among the alternatives. In the event that we do not elect to decide our own future, the march of time will decide it for us.

Summary:

As we have seen, after 1950 our nation's energy system grew by leaps and bounds to its present complex state. We allowed it to grow without limitations on our fuel and energy requirements, as it appeared to most of us that we had sufficient resources at home to fill all our future needs. Our energy system now has built-in demands for large amounts of natural gas, oil, and electrical energy. These demands can no longer be easily changed and in the early 1970's they have exceeded our ability to fulfill them from our domestic supplies. Unfortunately, we have not yet developed the new and (sometimes) exotic energy forms which could have prevented increasing our oil and natural gas imports.

IV. EXAMINING OUR ENERGY SUPPLIES AND RESOURCES

In the following sections we will look more closely at our sources of energy to see how they reached their present position, and examine their future prospects and problems. We will also examine the ways we use energy and the likelihood of altering those patterns. Finally, we will analyze the impact on our energy balance of not meeting some of the assumptions or goals which were included in the forecast. As with any forecast, these projections reflect many assumptions which have been made regarding our ability to supply our various energy needs.

It is vitally important that the reader understand that the present situation cannot be dramatically changed with "the flip of a switch." In a system this large, change tends to be evolutionary, occurring over a period of years or even decades.

The forecast does not pretend to map out the future energy system as it will definitely exist, rather, it attempts to evaluate trends we have experienced in the past and possible changes we perceive for the future. Our energy system can be changed for the better or the worse. One of the questions we will have to answer is what type of energy system do we really want and are we willing to pay the price to have it?

Domestic Oil Production

The largest source of energy in the U.S. energy system is petroleum. The U.S. oil industry is mature and technically capable of carrying out a program for maximum production of our domestic sources. The United States is probably capable of predicting its domestic oil production with considerable accuracy for a 10 year period. The U.S. oil industry has had much experience in anticipating a finding rate, numbers of dry holes, and costs of production.

Historically, from the 1930's into the 1960's, the United States had considerable excess petroleum production capability. In fact, the United States was the world's leading petroleum exporter for decades. In 1975, however, we produced less than 65% of the petroleum which we consumed. (When considering all oil exports since 1900, the United States was, as of 1975, still the world leader, although this lead will be short-lived.) Recent experience has shown that our productive capability peaked during 1970 and has since been slowly but steadily decreasing. The rate of decrease in production varies, but it has averaged roughly 5% per year. *(Open Foldout L.)*

In certain key petroleum-producing areas, this decline has been even more dramatic. For example, Chart 1, Foldout L, shows the recent production experience of the state of Louisiana — which for years has been one of the leading U.S. oil and natural gas producers. For Louisiana the decline has been more than 9% per year.

This decline in production both for the United States as a whole, and individual states such as Louisiana, was accurately predicted by many experts. Studies and forecasts made in the 1950's and early 1960's generally predicted that U.S. production of crude oil would peak either in the late 1960's or early 1970's.[8]

Any oil well has a limited life of economic operation. Chart 2, Foldout L, shows the expected annual production rates and lifetime of a typical oil well. As the chart indicates, the initial levels of production are quite high; however, they begin a rather steady decline until, after several years, they reach the point beyond which it costs more to produce the oil than it will bring on the market. At that point, the well is shut down.

For the United States, the decline in production in 1970 has probably signaled many things regarding our future oil production. First, most experts in this field believe that the production of crude oil in the lower 48 states and the traditional offshore areas will continue to decline. Furthermore, these areas are unlikely to be the source of significant new discoveries. (Since 1859, more than 2 million holes have been drilled in these areas in search of oil or natural gas.) Second, major new sources of crude oil will come from the more remote areas, such as the outer reaches of the Gulf of Mexico, the outer continental shelf along the Atlantic Coast, or Alaska. This means we will have to go farther, drill deeper, at greater costs, under harsher conditions to produce new crude oil. Because traditional sources are declining steadily, new sources will be essential even if we only desire to maintain a fixed level of production. Overall increases in crude oil production will require a significant commitment of capital, technology, equipment, and skilled personnel.

Recoverable Resources is a term used by organizations such as the United States Geological Survey (U.S.G.S.) to describe the volume of oil which is believed, under an assumed set of market conditions, to be recoverable from the United States. A recent detailed study performed by the U.S.G.S.[9] concluded that *Recoverable Resources* were probably in the area of 144 billion barrels of oil (the mean point of its estimates). This figure included all categories from proven reserves through undiscovered resources which are believed to lie offshore or in remote areas of Alaska that have not been extensively

explored.[10] To place this number in perspective, the United States has produced 106 billion barrels of oil during its history through 1975. Domestic oil production for 1975 stood at roughly 3 billion barrels. Consumption (which also includes imported crude and imported petroleum products) is roughly 5 billion barrels per year.

As a very general gauge of the U.S. resource base, the *Recoverable Resources* can be roughly measured in terms of years of supply. While this yardstick is admittedly over-simplified and must be used carefully, such a measure does place the resource estimates in an understandable perspective. If we view these resources in terms of our *current production,* then 144 billion barrels is equivalent to a 48 year supply. If we assume that we increase production to our *current consumption* levels (i.e., about 5 billion barrels per year), then our resources would provide less than a 30 year supply. If one attempted to meet all of our oil requirements as shown in the preceding forecast (reaching 18.8 MB/DOE by 1990 or 6.9 billion barrels per year), then our resources would yield roughly a 25 year supply. (These calculations assume that production would occur evenly throughout the time period, even when approaching the last remaining supplies. This is a highly unrealistic assumption; nevertheless, it makes the point that our oil resources are finite.)

While one can argue about how fast we will use up our oil resources, the implications seem clear. Oil is a limited resource which will probably become too valuable for the United States to use merely as a fuel well within the lifetime of most of those now entering college, starting families, or embarking on careers. *(Close Foldout L.)*

Oil Shale

Oil shale is one of our larger energy resources and is found in many states, particularly Colorado and Wyoming. While the technology is available to produce oil from shale, several demonstration plants may be required to prove that such a venture is commercially attractive. In order to produce 1 million barrels of shale oil per day using surface technology, it would be necessary to have massive mining operations with total daily tonnage of material handled in excess of our present coal production. Water requirements to support such an undertaking would be staggering in this semiarid region.

The technology for the "in situ" process (i.e., underground liquification) is still in its infancy. Recent project cancellations and deferrals have no doubt set back the time schedule for the development of such processes. The primary reasons given for the deferrals are the soaring cost of facilities (a recent estimate for a 50,000 barrel-per-day plant reached $800 million) and potential environmental problems. As a result, by 1980, it would seem unrealistic to expect any sizeable contribution to our energy system from oil shale.

Oil Imports

The United States is currently importing between 6 and 7 MB/DOE of crude oil and petroleum products. These imports represent more than 35% of our petroleum needs and the percentage has been increasing, even during the rather severe recession of 1974-75 when oil consumption was declining. Fortunately, by chance or planning, our sources of oil have been well-spread throughout the world. In the past, most of our imports have come from the western hemisphere (Canada and Venezuela) with smaller amounts from Africa and the Middle East (Nigeria, Iran, Saudi Arabia).

Recently, Canada, which had been our leading supplier, shifted from an oil surplus to an oil deficit position. Because of this reversal and a reassessment by Canada of its energy policies, the Canadian government has announced its intention to cut back gradually oil shipments to the United States, completely terminating them by the early 1980's. Likewise, Venezuela has indicated that it should not be considered a future source for U.S. oil supplies at a rate higher than the present level. As a result, the United States is currently receiving a much larger share of its oil imports from Africa and the Middle East. This shift has occurred since 1972-73 despite our experience with Arab oil embargo. Foldout M shows the changing makeup of U.S. oil imports and the shift from the western to the eastern hemispheres. *(Open and examine Foldout M, then close Foldout M.)*

Such a shift raises the possibility of the future use of the "oil weapon" as an instrument to apply pressure in forcing the resolution of foreign policy issues or international crises. Because of this concern, the United States, as a matter of national policy, has set the goal of achieving some form of "energy independence" or "self sufficiency".

"Third World" demands for petroleum may be an even more important reason for us to set some reasonable limit to our imports. Worldwide demand for petroleum has been increasing at a rate of 5.6% per year in the 1960's (doubling every 13 years). In many of the less developed countries, petroleum is an essential resource upon which rests their industrial and agricultural development. These needs are so basic that they cannot be deferred and will probably continue to expand despite higher oil prices. In addition, most highly industrialized countries are heavily dependent on oil imports to meet their energy needs. In short, the worldwide demand for oil is likely to continue its upward climb due to the pressures of increasing population, desire for an increasing standard of living, and general economic growth. How we are going to share and use this finite resource is an international as well as a national concern.

Coal

In terms of resources, the United States is handsomely endowed with vast coal deposits. Some estimate that at current levels of production we have sufficient supplies to last for 500 years; however, there are problems.

Through the first 100 years of our industrial history, coal was the dominant fossil fuel. This supremacy over other fuels was maintained until shortly after World War II when oil replaced coal as our leading source of energy. There are many underlying reasons for this shift in fuels. The most important are probably the relative costs of the fuels, the ease of handling and transporting liquids (or gases), and the responsiveness and controlability of oil and natural gas. In the late 1960's and early 1970's, environmental concerns led many electric utilities to shift from coal to natural gas or oil fired generating plants. (Subsequently, there were pressures to revert back to coal following the Arab oil embargo.)

Today, coal's primary difficulties would appear to be environmental. From the initial mining process through and even beyond the burning process, coal runs headlong into a series of environmental problems. Strip mining has long been a political and emotional issue, particularly in our western states. On the other hand, underground mining is associated with some safety hazards and higher costs as well as environmental problems.

The environmental concerns regarding air pollution make it highly unlikely that coal will soon be used directly by other than large industrial users or electric utilities, due to the significant capital investment often required in order to burn coal in an environmentally acceptable manner.

In addition, the coal distribution system needed to serve smaller users in most urban areas has been dismantled or is in an advanced state of deterioration. Since most coal is moved by rail, any increase in coal production must be complemented by some restoration or rehabilitation of our rail transportation system. This system, particularly in the eastern part of the United States, is in poor condition.

Natural Gas

The availability of natural gas has commanded considerable attention during the last few years, particularly during the winter heating season. Natural gas is the leading energy source for residential, commercial, and industrial users, but in many regions of the country there is a moratorium on new natural gas line hookups — preventing new houses, stores, or industries from using this premium fuel. Also during the past few years, most industrial users located outside of the major gas producing areas have had their supply of gas interrupted for varying periods of time. When possible they have shifted to other fuels, in most cases liquid propane or oil. For the most part, only those industries which are unable to operate using other fuels have been exempted from natural gas service interruptions.

Discovered reserves of natural gas reached their highest level in 1967 and since then have declined precipitously. These reserves might be thought of as an underground inventory from which natural gas is drawn to supply customers. As the stock or inventory decreases, the ability to supply customers also decreases. Recent assessments of our recoverable natural gas resources by various independent agencies have indicated that our resources may be more limited than they were once thought to be. In December 1974, the Federal Power Commission published a paper entitled *A Realistic View of U.S. Natural Gas Supply*,[11] which stated:

> "Events of the past few years have tended to lend credibility to the lower range of estimates (natural gas resources). There has been a significant increase in the level of exploratory drilling for gas over the past several years, yet discoveries and reserve additions continue to decline. Presumably, the oil companies are drilling their best prospects but are finding few gas deposits of significant size."

This indicates that our experience with natural gas may be closely following that of oil. Recent production data indicate that natural gas production may have peaked in 1973. Whether we can again attain the 1973 level of production remains to be seen. At best it will be a difficult undertaking. Many experts believe we will not be able to sustain a level of production equal to that in 1973 for any length of time, no matter what the market price of natural gas.

While the future of natural gas production is difficult to estimate, we must conclude that we will not be able to use natural gas as a substitute for oil. In fact, the opposite situation is probably more likely to occur; oil may be needed to offset dwindling natural gas supplies.

Natural Gas Imports

The United States is currently importing some natural gas, primarily from Canada. Future projections have indicated that even higher levels of imports of natural gas may be needed in the years ahead. Generally, most of these imports were expected to come from Canada; however, as was mentioned for oil, Canada is reevaluating its energy position and is currently considering limits for export of all fuels, including natural gas. If such restrictions are applied to natural gas, this would force the United States to import natural gas from abroad via liquefied natural gas (LNG) tankers from countries such as Algeria or perhaps even the USSR. LNG shipments also present some problems regarding cost, investment, and possibly the environment.

Nuclear

It had been assumed by most forecasters that nuclear power would become a significant, if not the dominant, method for generating electrical energy in the last decade of the 20th century. Recently the outlook for nuclear power has changed considerably.

Table III: Nuclear Power Forecasts

Projected Levels of Installed Nuclear Capacity in 1985

Projection	1985 Capacity in MB/DOE*
1962 (AEC)	2.3
1971 (AEC)[12]	6.9
Early 1975 (FEA)[13]	3.7 to 5.7
Late 1975 (Electric World)[14]	3.8

*Normally the capacity of nuclear power plants is expressed in megawatts; however, in order to relate this energy source to our overall system, it is shown here in an oil equivalent energy form. This represents the amount of oil which would be burned to produce the same amount of electricity. It has been assumed for purposes of these calculations that nuclear power plants in 1985 would be operating at 60% capacity; 40% of the capacity is assumed to be unavailable as a result of maintenance, refueling, inspection, or reduced operating levels.

Table III points out the dramatic shift in estimates of nuclear power on line by 1985. Initially, projections indicated a rather slow growth pace, but the estimates accelerated rapidly during the early 1970's. By 1975, however, the outlook for nuclear power had changed and the estimates began declining.

Because of the present problems facing nuclear power, 1975 estimates of its contribution to our energy system could be greatly overstated. Recently, construction of new plants has been postponed or cancelled in large numbers. Since nuclear energy is used exclusively for generating electric power, its first substitute would probably be coal. The extremely burdensome capital investment as well as the recent reduction in the rate of growth of electric power demand have been responsible, at least in part, for the marked decrease in nuclear power plant construction.

A more imposing hurdle may be the movement in many areas to require state approval for construction of nuclear power plants. Such legislation, if approved, seems destined to delay, if not to halt altogether, the construction of nuclear power plants in these states. Many states still have petitions or referendum movements under consideration.

Because it takes 8 to 10 years to plan, find a site, and construct a nuclear facility, any plants not currently in the planning phase will not be operational by 1985. Therefore, the 1975 projection should be viewed as an upper limit. Actual capacity on line will most likely be below this level.

Geothermal

Despite present technical unknowns, our geothermal capacity would be fairly predictable once we decide what environmental tradeoffs we are willing to tolerate and what amount of capital we will commit to the development of such power. The projection for 1990 shows output from geothermal in the range of 1 MB/DOE. This is an ambitious program. Geothermal power of this magnitude would require a massive effort in California and other areas favorably disposed to such undertakings. Recent defeat in the House of Representatives of a loan guarantee amendment designed to guarantee loans for the development of oil shale, coal conversion, and geothermal energy will make this target even more difficult to attain.

Solar

A study[15] prepared for the National Science Foundation to evaluate the prospects for solar heating and cooling of buildings concluded:

> "Left to the interaction of the free market, solar systems will become competitive with conventional heating and cooling when equipment, operation, maintenance, and fuel cost of the one are similar to those of the other over their projected useful life. It is the conclusion of this study that, in general, a parity will be reached about 1985, and that general acceptance and widespread use will follow in two or three decades."

The report went on to state that to hasten the feasibility of solar systems would require an immediate and broadly based effort in research, development, and demonstration.

The projections for solar energy which have been used to construct the charts assume that we will undertake such an immediate and broad effort and that it will be successful. While solar power is an attractive alternative for space and water heating, it still faces many hurdles — among these are the need for continuing development of the technology, improving its competitive position with fossil fuels (it is presently marginal at best), and the developing of an industry to produce, install, maintain, and service solar systems. In good measure these problems are interrelated and the speed with which they will be resolved is somewhat unpredictable. The future contribution of solar energy is cloudy at best.

Synthetic Fuels

The primary problems associated with the use of coal lie in its handling, control, and the environmental problems encountered when it is burned. Since coal is an abundant resource in the United States, an attempt to work around these problems has led to considerable interest in synthetic oil and natural gas extracted from coal. While neither process is entirely new, the technology is still being developed. Today the primary problems appear to be essentially economic. Again, high capital costs, technological uncertainty, and the uncertainty of a commercially competitive product have caused the development of these fuels to proceed slowly.

Hydroelectric

Our hydroelectric capacity can be projected with reasonable reliability. The United States has not been blessed with abundant hydroelectric potential; it has been estimated that we have probably already developed more than half of our potential. Many of the remaining sites lie in national parks or scenic areas, such as the Grand Canyon. It is unlikely these areas would be developed in the near future.

Recently, there has been a renewed interest in tidal flows as a source of hydroelectric power; however, no major projects are currently underway or actively being planned. Such projects are sure to be subject to extensive scrutiny to determine their ecological impact and economic payoff.

In short, hydroelectric capacity is unlikely to be the source of a significant increase for our energy supply in the foreseeable future. The forecast used on our charts for hydroelectric power is probably very close to what may realistically be expected from this source.

Summary:

Our energy system relies heavily on oil and natural gas. Unfortunately, our supplies of these resources are rapidly dwindling and domestic sources are unable to keep pace with demands. To offset this deficiency we have used oil imports and may have to continue to import oil for years or even decades to come. But world oil resources are also limited and world demand is growing at a rate even higher than ours; therefore, imports can provide only a temporary solution, and that at a substantial price. Abundant coal resources exist in the United States; their use, however, is beset by environmental problems and other difficulties. Newer and more exotic energy forms are still unable to provide significant inputs into our energy system and many are themselves beset with environmental, economic, and technical problems.

V. EXAMINING OUR ENERGY DEMANDS

In the preceding sections, we have attempted to outline the U.S. energy system as it appeared in the past and may appear in the future, examining our past and possible future energy sources. We have examined our energy flow patterns for six years and we have also looked at various aspects of our system over 40 years. In this section we will look beyond our display charts and try to examine some of the complex factors which have molded our past energy consumption and which will influence our future choices.

Population

It is clear that population has an effect on energy demand. Each person needs food, clothing, and shelter — all of which require energy to be produced. The population of the United States is projected to increase from 205 million in 1970 to between 220 million and 226 million in 1980. By 1990, we can expect a population of between 236 million and 258 million people.[16] This means that we will add enough people to our population each year to inhabit a city the size of a Detroit, Michigan, or an Atlanta, Georgia. With this increasing population, the demand for energy can be expected to increase at least in some direct proportion to the population growth.

The Economy

One of the many key factors in our energy use pattern is the state of the economy. The factors which influence the energy consumption pattern in our economy are widespread and complex. As a result, there is not always agreement on the relative influence of these factors — one needs only to read the newspaper to see that this is a highly controversial issue. Nevertheless, there are some factors that are widely accepted as influencing energy consumption and it would be helpful to understand these — at least in some general way.

An important factor is the growth in the labor force. As a consequence of the age distribution of the population, it is projected that our labor force will grow from 86 million in 1970 to almost 102 million by 1980 and then to 113 million by 1990.[17] This growing labor force will need more jobs just to keep the same percentage of our population employed. Given our expectations of at least maintaining our present standard of living, our economy must grow to provide jobs for our growing labor force. As energy is a basic input for much of our economic activity, this implies that our energy usage must also increase as our GNP (Gross National Product) increases. *(Open Foldout N.)*

Historically, as we can see on Foldout N, energy consumption and GNP have exhibited remarkably similar behavior. This energy-economy link has been well documented by recent events. In 1975 not only did the petroleum price increase hit us fully, it was also the year in which we began experiencing the worse recession since the 1930's. While we are not trying to say that this recession was brought on entirely by our energy problems, nevertheless, historically there is a definite relationship between energy use and economic activity. *(Close Foldout N.)*

This very close relationship may be surprising at first; however, many of the principal indicators of economic health are energy related activities, such as bituminous coal production, freight car loadings, electric power generation, and automobiles assembled. Energy is a basic resource in our industrial and commercial activities.

Whether or not we can change this historical relationship between economic activity and energy use in a short period of time without creating serious economic consequences is a very controversial issue among many economists. However, this issue cannot be resolved exclusively in economic terms as other important considerations will weigh heavily on the outcome. Prominent among these are customs and habits, social values, environmental objectives, and individual values, many of which are often in conflict with each other. All of these factors will shape and alter the economic decisions we make. (The forecasts used in the energy flow charts assume that we will make some progress in altering the economic-energy relationship.)

The Environment

Another consideration which must enter our energy demand picture is the environment. Many projects which would help in solving our energy problem have serious environmental consequences.

Domestic energy production necessarily entails environmental tradeoffs. The Alaska Pipeline, the strip mining of coal, nuclear power, offshore drilling for oil, etc., all represent projects which would produce energy but which have varying degrees of environmental risk as a penalty. The choices we face are very difficult. If adequate supplies of energy are indeed a desirable goal, then what is the price we are prepared to pay in terms of the quality of our environment? By the same token, to what degree are we prepared to curtail our efforts for energy development to preserve the environment?

Our attempts to improve our environment affect our energy use patterns. Many people and organizations have taken steps to improve the quality of our water and air. Unfortunately, these anti-pollution efforts often carry a penalty of increased energy consumption. For example, it has been estimated that the 1976 automotive standards imposed a 15 to 30% *increase* in fuel use per vehicle mile.[18] In one case, admittedly extreme, pollution control devices installed in an electrical generating plant lowered the generating capacity of the plant by 20%. Pollution control devices can be effective; for example, smokestack scrubbers often can remove more than 98% of the particulate matter and sulphur oxides. They can, however, add significantly to construction and operating costs of generating plants and reduce a plant's electrical output by 1.5% to 5%. This may also increase the price consumers pay for electricity by a very discernable amount — some have estimated a 10% to 20% increase.[19]

It should be clear by now that environmental and energy considerations are often in conflict. It will be up to us as both consumers of energy and inhabitants of an ecosystem to choose a course that will accommodate both our energy and environmental needs. This choice will often be painful.

The Conservation Ethic

The composite forecast which has been developed for the energy display represents a very significant change from our historical performance. From 1960 through 1973, energy demand in the United States grew at an annual rate of nearly 4%. In contrast, the composite forecast is for an increase in energy demand of only 2.6% per year from 1974 through 1990. While the percentage difference may not be striking, a comparison of the difference in the magnitude of energy demand is indeed impressive as shown in Table IV.

Table IV: Energy Demand In 1990

4% growth from 1974	65.7 MB/DOE
2.6% growth from 1974	52.9 MB/DOE

This shift implies that we will use energy in a more thoughtful manner, conserving our energy resources where it is possible and reasonable to do so. This reassessment of values and customs is often referred to as the Conservation Ethic. This is assumed to occur under conditions of economic growth sufficient to provide the jobs for our growing work force as well as the housing, transportation, food, energy, and other goods and services demanded by our growing and more affluent population. The conservation effort will be essential in order to stimulate the replacement of equipment and facilities which are presently inefficient in their use of energy. Coupled with this conservation effort, the proper economic incentives should exist to convince consumers and industry alike that energy saving investments are an attractive method of reducing costs. We tend to replace old energy using equipment and buildings with newer energy efficient ones only as the old equipment wears out or becomes too costly to operate. Recent increases in energy prices will speed this process up to some degree, but it will still take time. (The effect of high prices in stimulating energy conservation highlights one of the dilemmas which our energy choices entail. Obviously consumers would prefer lower prices for all commodities. Such competing interests create strong pressures making policy decisions very difficult.) *(Open Foldout O.)*

In Foldout O, Step 1 shows the **Supply/Demand** cross plot for this projection; as we have seen, a modest conservation effort has been assumed. To appreciate fully the importance of this conservation assumption, we will first rearrange the cross plot by removing the open spaces and pushing together the solid areas (Step 2, Foldout O); next, we shift the imports of oil and natural gas to the top of our chart, thereby showing the magnitude by which our demand exceeds our domestic supply (Step 3, Foldout O).

The projected import (i.e., domestic shortage) levels are 7.9 MB/DOE in 1980 and 9.3 MB/DOE in 1990. Remember this shortage will occur *even* though we assumed the United States would *reduce* energy demands from a growth rate of 4.0% per year to 2.6% per year.

To appreciate fully the significance of this conservation effort, refer again to Step 3, Foldout O, which shows our energy balance with imports identified by the red shaded area. The dashed line above imports or shortages indicates the level of demand if we are only able to reduce the rate of growth in energy consumption to 3.4% per year instead of the 2.6% which we have assumed. Should this situation occur, then in 1990 our energy imports (shortages) would reach 18.0 MB/DOE instead of the current projection of 9.3 MB/DOE. This would result in our importing more oil in 1990 than we actually use today — a staggering 18.0 MB/DOE.

Clearly, conservation is important in our energy strategy; however, we must not believe that such a reordering of our habits and life styles will occur easily or quickly. Studies have shown that as

one's income rises, energy consumption also rises but at a faster rate.[20] This is due to the fact that as incomes rise, people have a tendency to buy energy using machines which do their work faster and easier, replacing human effort. Affluence thus can lead to an increase in energy demand, pointing out again that conflicts between increasing our standard of living may clash with our desires to conserve our energy resources. Again we see that changing human behavior is usually a slow, difficult process.

Certainly other options or changes designed to help meet our energy demands can be postulated and the impact assessed on the Energy Display System to determine their effects. The example of conservation was selected merely to show how the display can be used for evaluating our various energy options. *(Close Foldout O.)*

Summary:

Our energy demands are driven by such basic forces as population, employment, and a desire for an increasing standard of living. As a result, if we decide we must change these energy demands, we will first have to change our behavior patterns. Aside from this human factor which builds inertia into our energy system, there are several physical factors with which we must deal. There are already in existence large numbers of energy using buildings, cars, buses, appliances, etc., which make immediate change in our energy demands next to impossible. Retrofitting or completely replacing our buildings, cars, homes, etc., would take many years and a substantial capital outlay. Because of the very nature of our existing energy system, whatever course of action we choose to take will be many years in the making and will involve many decisions which, in all probability, will significantly affect all of us.

VI. INTO THE NEXT ERA

For most of us the "energy crisis" of 1973-74 was long gasoline lines and abruptly higher prices for heating oil and electricity. Now the lines are gone and inflation and time have begun to erode the memories of those sharp price increases. We have begun to forget the underlying problems which brought us to the crisis point. We assume that all is well, but the fundamental problem remains. *(Open Foldout P.)*

Foldout P provides a long-run perspective of our energy **Supply/ Demand** situation from 1900 through 1975 to a projected 2050. This picture reveals three very distinct phases of our energy life. From 1900 through the 1960's, the United States was an *energy surplus* nation. In fact, much of this time we possessed a considerable volume of shut-in oil and natural gas productive capability. Throughout the 1960's this excess capacity was being rapidly used up as the demand for energy increased at a high rate. By 1970 we reached the point where we crossed over from an energy surplus to an *energy deficit* nation. Furthermore, the rate at which demand increased ahead of supply literally vaulted the United States into an imported fossil fuel era.

The third section of this chart shows the deficiency of our energy supply system beginning in the early 1970's. Unfortunately we are not yet ready to replace our faltering fossil fuel supplies with non-fossil energy sources. Therefore, we are forced to import fossil fuels, oil in particular.

This chart should enable the reader to grasp better the meaning of the difference between the era of relatively cheap and abundant energy now ending and the emerging era of increasing needs for new and expensive non-fossil energy supplies and imported fossil fuels. The reader should notice that even a sizeable decrease in our energy demand and a major increase in our domestic fossil fuel supplies will only provide a few years respite in our national energy dilemma.

America has actually found itself in the "twilight" of the fossil fuel age. We have used the cream of our oil, gas, and coal resources as one of the basic building blocks of a technical and industrial society the likes of which the world has never seen. We will now have to use our technical capacity to carry ourselves into the next energy "age" or "era". We could make this transition primarily by buying time through the next few decades with accelerated uses of our remaining domestic fossil fuel resources and by conserving and using our energy more wisely.

The greater the degree of determination of the United States to make the disagreeable and difficult decisions facing us — decisions regarding the development of new energy sources, the extent of our energy conservation efforts, the price we are willing to pay (both in dollars and environmentally) for accelerating uses of domestic fossil sources, etc., — the greater the chances are of resolving our national energy dilemma.

Time can either be an ally or our worst enemy. If we act quickly and decisively, then we can use the interlude ahead to resolve this dilemma. Conversely, if we fritter away these years with indecision and inaction, we will find ourselves with but a few options, all equally distasteful.

Fortunately, we will face this challenge better equipped to succeed than anyone has ever been. We have the world's most advanced technological base; we have skilled and knowledgeable managers, technicians, and scientists; we possess a talented and able labor force, and we have the organizational, economic, and financial resources to pull these all together to meet the challenge. But first, before we can wisely use our talents and resources, we must recognize the problem and decide which course of action we are going to take. *(Close Foldout P.)*

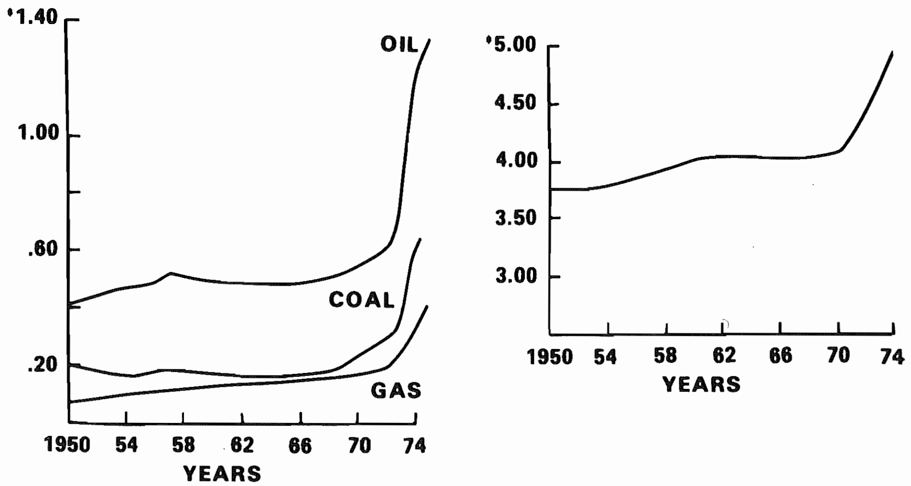
APPENDIX A

Energy Prices

Since 1973 attention has been directed primarily at oil prices; however, almost all energy prices have risen dramatically during the past few years. Chart IV shows the prices for the three principle fossil fuels based on their cost per million BTU's. In addition, the average price for 100 kilowatt hours of electrical energy is also shown separately. (The two charts are not directly comparable.)

Chart IV:

A. Average Cost per Million BTU's by Fuel Type — **B. Average Electric Rates for Households for 100 Kilowatt Hours**



As can be readily noted, after years of more or less stable prices for all three fuels and electrical energy, in the late 1960's oil prices began to rise. Coal prices, lagging somewhat, followed suit. Electrical rates followed closely the shift in coal prices as much of the electric power in the United States is generated by burning coal.

Then in 1973-74, the prices of all three fuels rose abruptly. Most natural gas sales are regulated, and prices respond to regulatory decisions rather than to market forces directly. As a result, natural gas prices rose more slowly than coal or oil. Thus the OPEC actions of 1973-74 which were directed at petroleum appear to have had a widespread impact on all energy supplies.

The flow of revenues to those countries supplying the United States with oil are shown on Table V. The sharp increase in revenues is readily apparent between 1972 and 1975. It can be observed that prices were increased by all oil producers, both OPEC and non-OPEC suppliers alike. Interestingly, most of the funds leaving the

United States have gone, and still go, to non-Arab nations (for Japan and Western Europe this is not the case).

Table V: U.S. Payments to Foreign Nations for Oil Shipments[21] (Billions of Dollars)

Oil Exporter	1972	1975
Canada	$1.1	$3.2
Venezuela	1.1	3.3
Saudi Arabia	0.2	2.5
Iran	0.1	1.3
Nigeria	0.3	3.2

Much of the increased outlays, not only for oil but other energy forms, stayed within the United States. For some large energy producing states this has led to dramatic increases in severance tax receipts on oil and natural gas produced within the state.

For example, in Louisiana receipts from taxes on oil and gas more than doubled between 1972 and 1974 even though the physical volume of production declined. Similar experiences occurred in many other energy producing states. As a result, the impact of energy price increases is unevenly distributed throughout the United States. The flows of tax receipts to local governments and income to local industries in energy producing states are viewed quite favorably by the recipient. Those states which are "energy poor", particularly along the east coast of the United States, experienced economic problems and perceive the energy situation as a threat to their economic health and well-being.

Thus, the rapid increase in energy prices not only created a flow of funds to foreign oil producers, it also created a flow of funds within the United States to the major energy producing areas. Related to this latter factor there was a noticeable upsurge in regionalism in the United States during the 1974-75 period. These feelings are still prevalent to some extent.

This relative change in all energy prices has also created considerable uncertainty on the part of energy users regarding the long-run economic outlook for the substitution of one fuel for another. As a result, the anticipated shifts from oil to other fuels have not materialized as rapidly as some had expected.

APPENDIX B

Energy Forecasts For 1980 and 1990

The projections of energy supply, demand, and end use developed for this publication represent a composite of many forecasts made since the oil embargo and the energy crisis of 1973-74. These specific projections were chosen because they cover a broad spectrum of sources and have been widely used and cited in speeches, papers, and testimony on energy matters. In selecting these it was our intent to benefit from the perspective of those in the academic community, business, and government. We have also attempted to receive the benefit of the different outlooks that various disciplines may have on our energy future, e.g., one forecast is an economic view, another the view of an engineer, an environmentalist, a scientist, and so on.

In this effort to balance or average our view of the energy future, we have assumed that an extreme position on either side, high or low, is unlikely to occur. At one extreme (as in high forecasts), it is assumed we do little to change our energy future, while at the other extreme (low side) it is assumed we will take very dramatic and severe actions. Due to the basic political nature of the energy choices and courses of action, it would seem, from our perspective, that neither case is likely. The problem is recognized to be serious by some of those in political life, and some legislative changes have been and will continue to be enacted. On the other hand, the problem is no longer viewed with the crisis mentality so necessary for drastic change. As a consequence, we believe the balanced forecast that arises from this process of combining many viewpoints is probably a fair assessment of our energy future.

As in any averaging process, the overall energy projections are probably more reliable than the projections for specific fuels or end use estimates. Specific events or legislation can dramatically influence a specific fuel or use, e.g., nuclear power or oil shale; however, these same events are unlikely to change significantly the overall levels of energy use.

The list below identifies the ten projections used to calculate the composite forecast. In most cases, simple averages were used to arrive at the composite figure. However, not all forecasts contained all of the desired information. On occasion, additional information was obtained from these sources to fill in some of the missing pieces. (e.g., on specific fuels, user categories, or specific years). In other instances, subjective judgments were employed to weigh the available data to retain the integrity of the forecast. Hopefully, these instances have been kept to a minimum and it is our belief that they do not in any way detract from the central theme of this paper.

LISTS OF FORECASTS USED TO PREPARE THE PROJECTIONS DEVELOPED FOR THIS PAPER

Council of Environmental Quality, "A National Energy Conservation Program: The Half and Half Plan," March, 1974.

Energy Research and Development Administration, "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future," Volume I: *The Plan*, ERDA 48, June 28, 1975.

EXXON Company, USA, "Energy Outlook 1975-1990," 1975.

Federal Energy Administration, "Project Independence Report," November, 1974. (Two cases were selected from this source.)

Energy Policy Project, "A Time to Choose," sponsored by the Ford Foundation, 1974.

Lawrence Livermore Laboratory, "An Assessment of United States Energy Options for Project Independence," September, 1974.

Massachusetts Institute of Technology, Energy Laboratory Policy Study Group, "Energy Self Sufficiency: An Economic Evaluation," *American Enterprise*, 1974.

National Petroleum Council, "Energy Preparedness for Interruption of Petroleum Imports to the U.S.," September, 1974.

Westinghouse, "Testimony by John W. Simpson before the House Ways and Means Committee," Supported by Westinghouse Publications, March, 1974.

APPENDIX C

"Where Do We Go From Here?"

The following questions are not a quiz, in fact the answers to most of these questions *cannot* be found in the book. Since many of our readers complained of being left with the feeling of "What next?", these questions were designed to point out a few of the areas needing further study on the part of the reader. There are many issues the reader must explore before he or she can decide how best to enter the next "Energy Era". This is not a complete list by any means — merely a beginning.

The book advocates no particular solution to our "energy crisis" but rather tries only to reawaken the reader to this most serious challenge and to encourage him or her to weigh our energy alternatives — to go beyond the scope of this book. Hopefully, the reader can use the Energy Display System to help visualize the impact of various options, using the common "language" of MB/DOE, on our total energy picture.

QUESTIONS — GROUP A

1) In what countries are the world's petroleum deposits located?
2) Where in the United States are our deposits of oil, coal, natural gas, oil shale, uranium, and sites for hydroelectric dams located?
3) How do you save energy by recycling products? What sorts of products are recyclable? What recycling programs are going on in your neighborhood?
4) What in your school / in your home / in the garden } uses energy?
   Which of these items would you *want* to give up to help conserve energy? Which of these would you *have* to give up if the cost of energy doubled?
5) What in the hospital / in the garden / in your car / in the department store / in your home / in the hardware store } is made from petrochemicals?
6) Compare the various modes of transportation to see how we can most efficiently move people and things — comparing the fuel use per passenger mile. Look at: cars and buses (gasoline, electric, diesel), planes, boats, trucks, horses, walking, bikes, motorcycles, hot air balloons, trains, and other ways of moving around.

7) How do we use energy in sports?
   What sporting goods are made from petrochemicals?
8) When you are on vacation, in what ways do you use energy?
9) For every barrel of oil you use, how many "man hours" do you save?

QUESTIONS — GROUP B

1) Compare the efficiencies of the different ways of generating heat — burning firewood, burning coal directly in the home, converting coal and oil to electricity and using electricity to heat, coal and oil furnaces, solar heating, etc.
2) How would you design a house to be as energy efficient as possible? Explore the use of solar, wind, heat pumps, use of dirt as insulation, window design considerations, "traditional" insulating procedures, recycling waste heat, etc.
3) Calculate the costs involved with various conservation efforts on homes and office buildings already in place — the long-range costs (of adding insulation, storm windows, curtains, recycling waste heat, stopping leaky faucets, etc.) versus the savings resulting from these energy conservation efforts.
4) Calculate the conversion efficiency of automobiles (gasoline, electric, and diesel models) (fuel/pound feet equivalent; auto performance/mpg).
5) Which countries have what percentage of the world's deposits of petroleum, natural gas, coal, uranium, and oil shale?
6) Which U.S. industries are totally and which are partially dependent on petroleum? Which industries are "energy intensive"? Which are not "energy intensive"?
7) What percentage of an average barrel of crude oil goes towards its various end products in a typical U.S. refinery? (What percentage is made into gasoline, diesel fuel, home heating oil, petrochemical stock, jet fuel, and other products?)
8) Compare various appliance efficiencies — also their energy cost, i.e., considering also how much energy was used in their construction.

   a. air conditioners versus fans
   b. incandescent versus florescent light bulbs
   c. gasoline lawn mower versus electric mower versus push mower
   d. elevators versus escalators versus stairs
   e. dishwasher versus by hand with hot water

9) What legislation presently before Congress (if passed) would affect our present and future energy supply — what sorts of legislation should be introduced to help solve our energy dilemma? What are your Congressmen and Senators proposing in the way of energy legislation? What is your state legislature doing in the way of energy legislation?

QUESTIONS — GROUP C

1) What is the present "state of the art" for oil from shale, coal gasification, solar heating, solar cooling, geothermal energy, nuclear fission and fusion, energy from the wind and tides — what can/cannot they do? What problems must be solved to make these "new" technologies economically and environmentally feasible?
2) What percent of their total energy supplies must Japan, Great Britain, the African nations, France, Mexico, China, and other countries import?
3) In what different way would the industrialized or developing nations be effected by energy cost increases?
4) What is the efficiency comparison between raising cattle, chickens, grains, and direct conversion of crude oil to digestible protein? Consider the fuel consumption for growing food and feed grains, fertilizer production, care and maintenance of livestock and crops, processing the foodstuffs, transportation, and cooking.
5) What are the mechanics behind electrical conversion losses? How might these be lessened?
6) Construct a graph comparing the price of a specific fuel with the various executive and legislative decisions designed to influence that fuel. Aside from these, what else has kept the price of energy in the United States lower than that of most other countries? Consider political reasons for keeping prices artificially low, consumer use patterns, the U.S. resource base, growth of U.S. oil industry, competitive position of U.S. products, etc. What, if any, were or are the political and social advantages for keeping our energy costs low?
7) By region or state, what would the effect of an increase in the cost of a particular energy source be in the United States? Study both the positive (increase in tax revenues for oil producing states, for instance) and the negative effects of such fuel price increases. Examples: How would an increase in natural gas costs affect the Northeast as opposed to the rest of the country? What states would be most affected by an increase in coal costs?
8) We are all sometimes guilty of thinking, "The other guy is the wasteful one. Let him give up his second car, his boat, or his

camper." How can we fairly allocate our fuel supplies during times of scarcity both nationally and internationally? How can we keep mandatory conservation efforts from hitting our lower classes the hardest?

9) What are the pros and cons — social, political, economic, and philosophical — for such "energy related" topics as: divestiture of the oil companies, increasing the number of nuclear power plants, massive efforts to mine U.S. coal deposits, offshore drilling, dealing with the oil cartel, pursuing "no growth" policies, and the extent of government-imposed conservation efforts?

FOOTNOTES

[1]The projections and more recent history were obtained from a host of published sources. For an explanation of the methodology used to develop the projections used in this book, see Appendix B.

[2]On occasion the numbers on the display charts will not appear to total exactly. This is due to "rounding off" the large number of calculations made.

[3]The method of calculating energy use efficiencies is somewhat arbitrary and of necessity based on very general estimates. The reader should be aware that there is another method of calculating efficiencies (based on the Second Law of Thermodynamics) which calls for a much stricter accounting of energy use, taking into account the quality of the energy in terms of its work potential. Using these rules, much lower efficiency measures would normally be obtained.

[4]Bureau of the Census, *Statistical Abstract of the United States 1974* (p. 705) Table 1205.

[5]Bureau of the Census, *Statistical Abstract of the United States 1966* (pp. 574 and 583).

[6]Extrapolated using Motor Vehicles Manufacturers Association *1975 Automobile Facts and Figures.*

[7]The reader can relate this efficiency curve, for example, to that part of Foldout E where in 1980 the rejected energy (or loss) was 20.2 MB/DOE and the useful energy was 18.2 MB/DOE.

[8]Most notable among the Cassandras was M. King Hubbert who in 1962 published an analysis that predicted with uncanny accuracy when the peak production would occur. *Energy Resources*, M. King Hubbert, National Academy of Sciences — National Research Council, Publication 1000-D, 1962.

[9]*Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States*, Geological Survey Circular 725; Miller, Thompson, et al., U.S. Dept. of Interior Geological Survey, 1975 (p. 4).

[10]The U.S.G.S. Report (cited in Footnote 9) stated that the range of error in such estimates was large and that the low side was estimated to be 112 billion barrels, while the high side of the range stood near 190 billion barrels.

[11]"*A Realistic View of U.S. Natural Gas Supply*," Staff Report, Bureau of Natural Gas, Federal Power Commission, December 1974 (p. 5).

[12]*Forecast of Growth of Nuclear Power*, U.S. AEC, Division of Operations Analysis and Forecasting, January 1971.

[13]Testimony by Roger La Gassie, Assistant Administrator for Planning and Analysis for ERDA, before the House Committee on Interior and Insular Affairs Subcommittee on Energy and the Environment, April 28, 1975.

[14]"Long Range Expansion Plans Act in Response to Lowered Growth Rates" in *Electric World*, September 15, 1975 (p. 47).

[15]*Solar Heating and Cooling of Buildings, Phase O*, prepared for the National Science Foundation by Westinghouse Electric Corporation. Final Report, Executive Summary, May 1974 (p. 5).

[16]*Statistical Abstract of the United States 1975* (p. 8). The range reflects the Census Bureau's projections I, II, III & II-X.

[17]*Ibid*, (p. 344).

[18]Eric Hurst, "The Energy Cost of Pollution Control" in *Environment*, Volume 15, October 1973 (pp. 38-39).

[19]*Fortune*, February 1975 (pgs. 109 and 112).

[20]Bureau of Labor Statistics, *Consumer Expenditures and Income: Survey Guidelines, 1971* (p. 99).

[21]U.S. Dept. of Commerce, *U.S. General Imports, Schedule A*, December 1975, (pp. 2-122). Dollar figures reflect Customs Value.

The reader will *not* find here complete definitions of the words and phrases. Instead, the "basic" definitions given, hopefully, will be enough to help the reader understand the text of the book as a whole rather than make him or her an "expert" on any one expression.

Bituminous Coal: also called "soft" coal; it has a brittle, bright luster and usually contains sulfur. Soft coal has less carbon and more water than "hard" (anthracite) coal.

BTU: the British Thermal Unit is the amount of energy necessary to raise the temperature of one pound of water by one degree Fahrenheit (when the water is 39.2° F. originally).

Crude Oil: the unrefined state in which petroleum is found as it is drawn from the ground. Also called simply "crude".

Dry Hole: a well that was drilled but was found not to contain any useful quantities of petroleum or natural gas.

Economically Recoverable: oil, natural gas, etc., is economically recoverable if the company that extracts the fuel can then sell it for enough to cover its costs, including some return on its investment.

Electrical Generating Plants: large plants that use some primary source of energy (coal, oil, nuclear) to produce steam, which in turn runs the turbine generators that produce electrical energy.

Coal Fired: a plant in which coal is burned to produce the necessary steam.

Nuclear: a plant that uses the heat produced by the nuclear reactor to make the necessary steam.

Oil Fired: a plant in which oil is burned to produce the necessary steam.

Hydroelectric: a facility that uses the forces of falling water to turn generators to produce electricity.

Energy: the *capacity* to do work as compared to "power" which is the rate at which work is done.

Chemical: examples of chemical energy are explosives, photosynthesis, and the energy we get from food.

Heat: an example of heat energy is the open flame of a fire.

Electrical: an example of electrical energy is lightning.

Mechanical: examples of mechanical energy are waterfalls, windmills, and steam turbines.

Radiant: examples of radiant energy are ovens, steam heat radiators, and heating pads.

Finding Rate: the percentage of the wells drilled which find petroleum or natural gas deposits.

Fossil Fuels: petroleum, natural gas, and coal are all fossil fuels; they are remnants of plants and animals from the distant past which were stored in the earth's crust and transformed to their present state over the years by intense heat and pressure.

Flue Ash: a visible pollutant that comes from burning coal.

Gas Service Interruptions: occur when the supply of gas is temporarily cut off; it is usually a means of rationing supplies when a scarcity situation exists. Normally industrial and commercial users are first to have their service interrupted.

Geothermal Energy/Power: heat energy from hot rock, hot water, or steam coming from beneath the earth's surface. (The natural steam geyser called "Old Faithful" in Yellowstone National Park is a famous visible example of geothermal energy.) It can be used either to produce electric power or for direct heating.

GNP (Gross National Product): widely used measure of economic activity in the United States; the total market value of goods and services produced by a single nation.

Hydroelectric Energy/Power: (see **Electrical Generating Plants**) electricity produced by water-powered turbine generators.

In Situ: as it applies to oil shale, an underground extraction process whereby the rock is heated in place to liquefy the oil in the shale which is then extracted from the ground by a conventional well.

Liquid Fossil Fuels: (see **Fossil Fuels**) fossil fuels that are found in a liquid state, such as petroleum.

Liquid Natural Gas (LNG): natural gas that has been cooled to about −260° F. for shipment and/or storage as a liquid; it has to be stored in pressurized containers, but in a liquid state it takes up less room than in its gaseous state.

MB/DOE: stands for the energy unit, million barrels per day of oil equivalent (see Table I). The table below can be used in converting figures to MB/DOE.

1 barrel (bbl. or B) = 42 gallons.

1 bbl. crude oil = 5,800,000 BTU.

1 kilowatt hour (kwhr) = 3.412 BTU.

1 kilowatt hour (kwhr) = 1 man-day of hard labor.

1 cubic foot natural gas (CH_4) = 1,000 BTU.

1 ton coal = 26,000,000 BTU.

Mix of Fuels or Fuel Mix: the proportion of the different types of fuels used for any one job. Examples: the nation uses coal, natural gas, oil, wood, nuclear, hydroelectric, solar, and geothermal resources to fill all its energy needs. We used oil, coal, and natural gas for transportation in 1950.

Non-energy Use for Oil: when oil is used to manufacture various products such as vitamins, plastics, fertilizers, and other chemicals.

For Coal: when coal is used to manufacture products, e.g., man-made diamonds.

For Natural Gas: when natural gas is used to manufacture products, e.g., fertilizer and chemical compounds.

Nuclear Energy/Power: greatly simplified, it is heat energy produced from a reaction involving change in an atom's center or nucleus. Fusion is where two light atomic nuclei combine; fission is the splitting of a single heavy atomic nucleus by a subatomic particle.

Oil Shale: fine-grained rock that upon heating produces kerogen (an oil yielding organic substance). One ton of oil shale rock can yield from 12 to 60 gallons of petroleum; the best U.S. shale yields 30 gallons per ton.

Oil Weapon: with our energy system so dependent on oil and with our inability to fill this need at home, those countries that have oil to export can apply pressure by restricting (or threatening to restrict) the supply of oil to the market. This oil weapon would have an effect on all countries that are heavily dependent on imported oil.

On Line: when a nuclear plant is "on line", it is out of its construction phase and is actually contributing electrical power to its customers.

Petrochemical: a chemical derived from petroleum or natural gas; such chemicals are widely used in plastics, synthetic fabrics, fertilizers, and a host of household and industrial products.

Petroleum: (also see **Fossil Fuels**) animal and vegetable materials that collected at the bottom of ancient seas, were then buried by inorganic residue, and subjected to great heat and pressure. It has a higher ratio of hydrogen to carbon than does coal.

Petroleum Products: (also see **Petrochemical**) when chemists rearrange the hydrocarbons of crude petroleum they can make gasoline, kerosene, jet fuel, home heating oil, and other chemical substances. There are about 3,000 products that are made entirely or partially from petroleum products.

Severance Tax: payment to the state for removal of oil and natural gas from the ground.

Shut-in Oil: petroleum that is known to exist in a field, but which cannot be brought to market because of lack of pipelines, unfavorable market conditions, lack of proper drilling equipment, etc.

Smokestack Scrubbers: an air pollution control device; often uses a liquid spray to remove pollutants from smokestack emissions. They are also used to reduce the temperature of emissions.

Surface Technology: recovery techniques that take place on the surface (such as strip mining or refineries) as opposed to underground technology (such as deep shaft mines or **In Situ**).

Synthetic "Natural" Gas: gas produced from the conversion of coal, crude oil, and other such carbonous materials. Its energy content may or may not be equal to the natural gas taken from the earth. The term "natural gas" has been used to avoid confusing this with gasoline.

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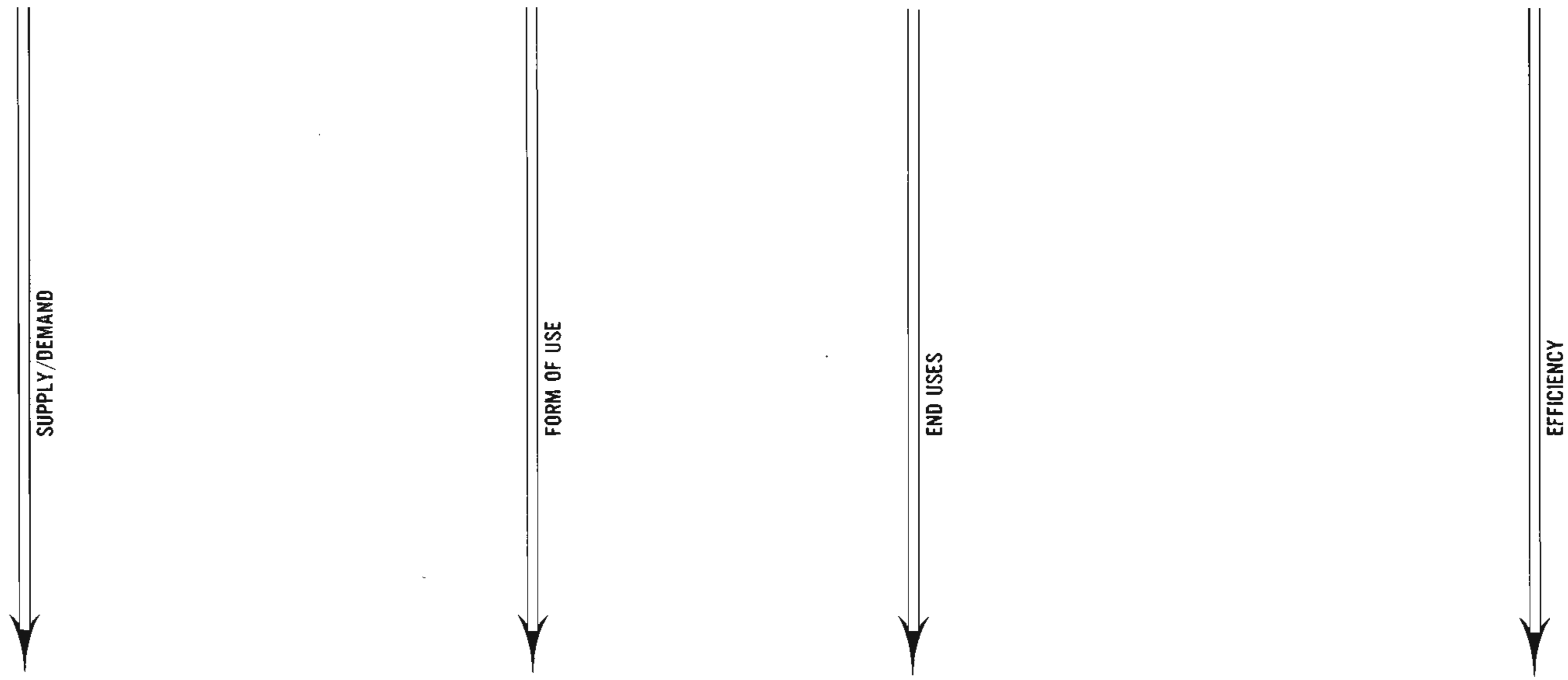
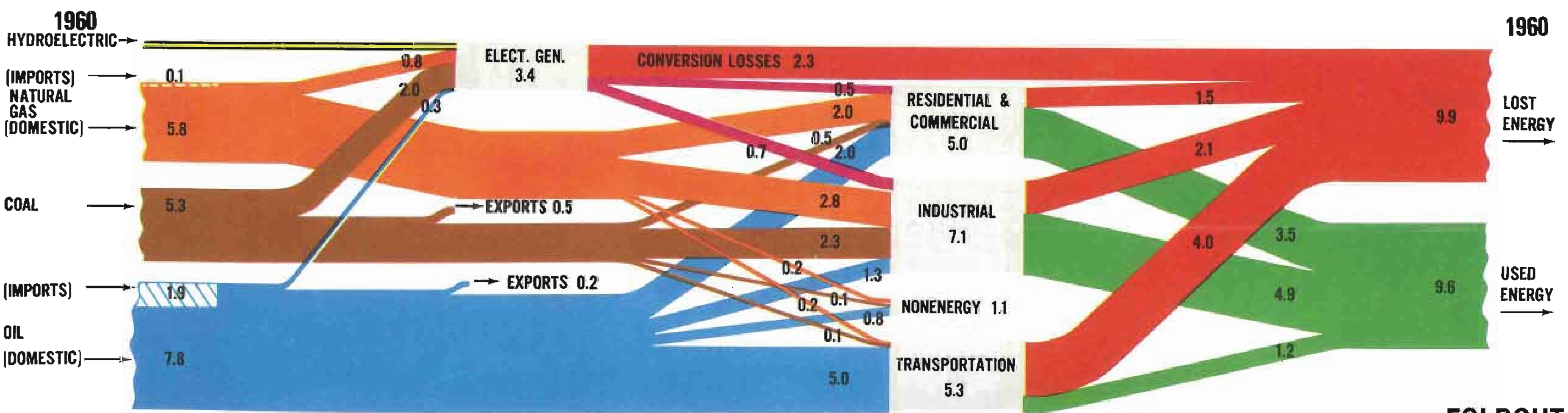

SUPPLY/DEMAND
FORM OF USE
END USES
EFFICIENCY


1960
HYDROELECTRIC
(IMPORTS)
0.1
NATURAL GAS
(DOMESTIC)
5.8
COAL
5.3
(IMPORTS)
1.9
OIL
(DOMESTIC)
7.8
0.8
2.0
0.3
ELECT. GEN.
3.4
CONVERSION LOSSES 2.3
EXPORTS 0.5
EXPORTS 0.2
0.5
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0.5
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0.7
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2.3
0.2
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0.8
0.1
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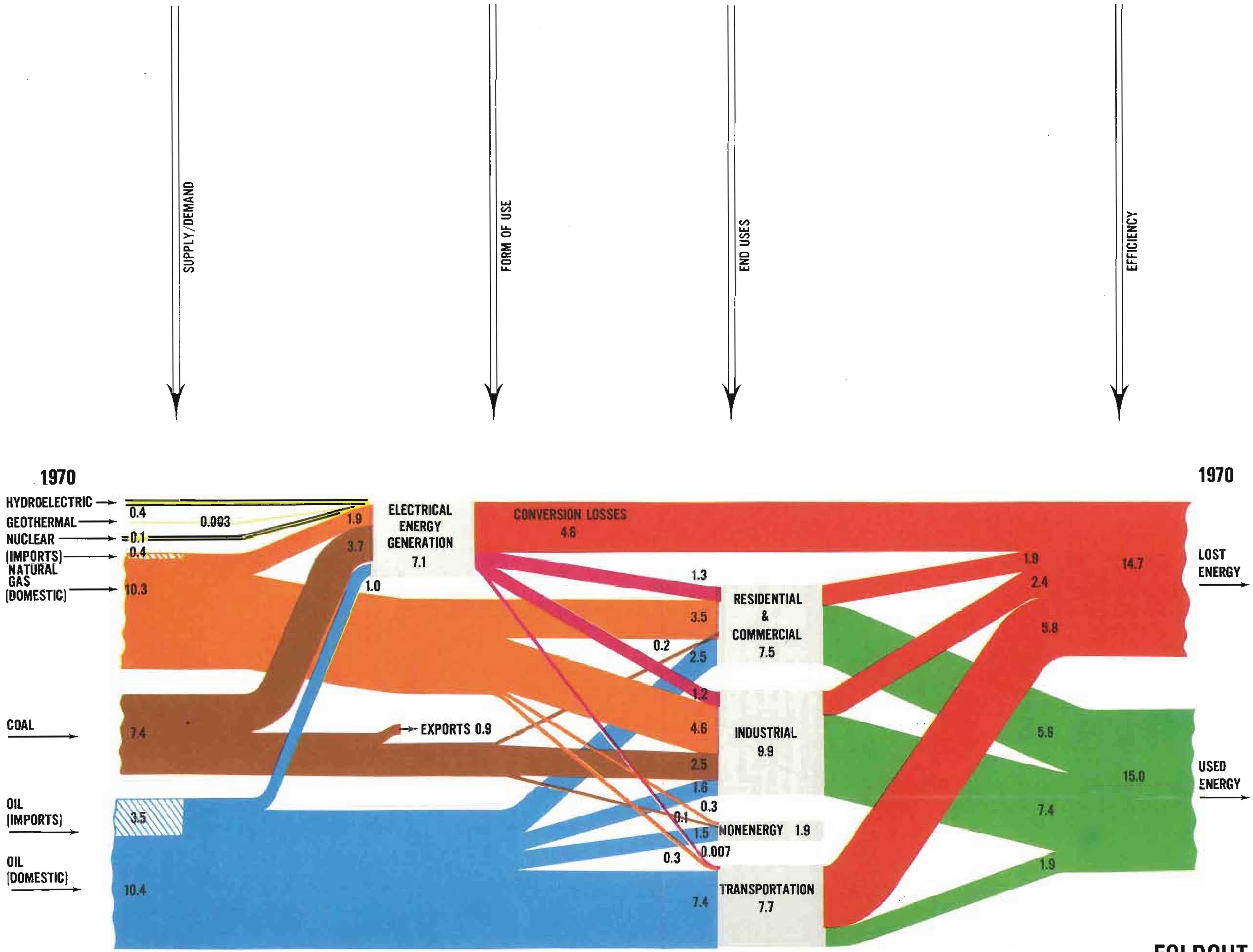
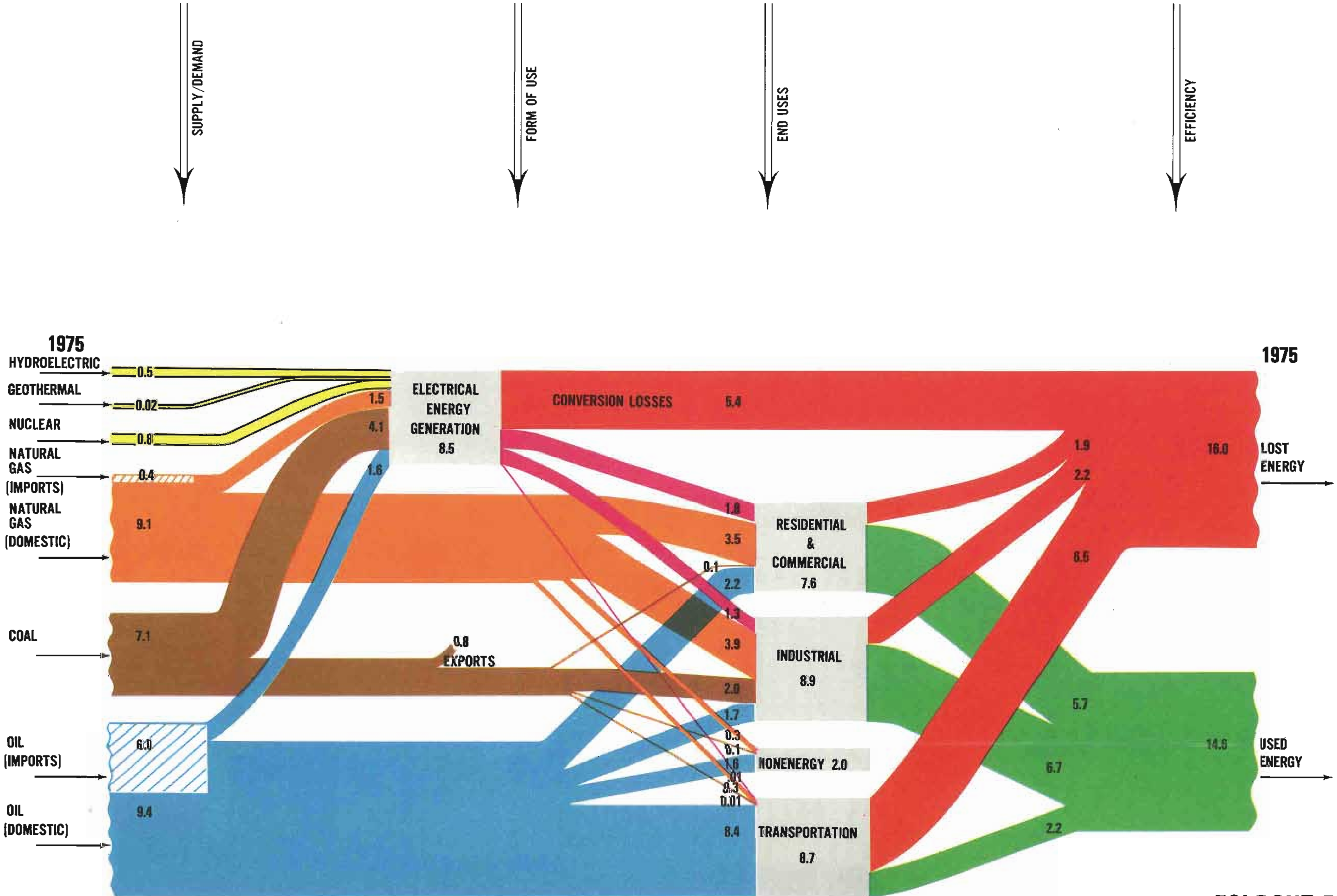
RESIDENTIAL & COMMERCIAL
5.0
INDUSTRIAL
7.1
NONENERGY 1.1
TRANSPORTATION
5.3
1.5
2.1
4.0
3.5
4.9
1.2
9.9
9.6
1960
LOST ENERGY
USED ENERGY

FOLDOUT B

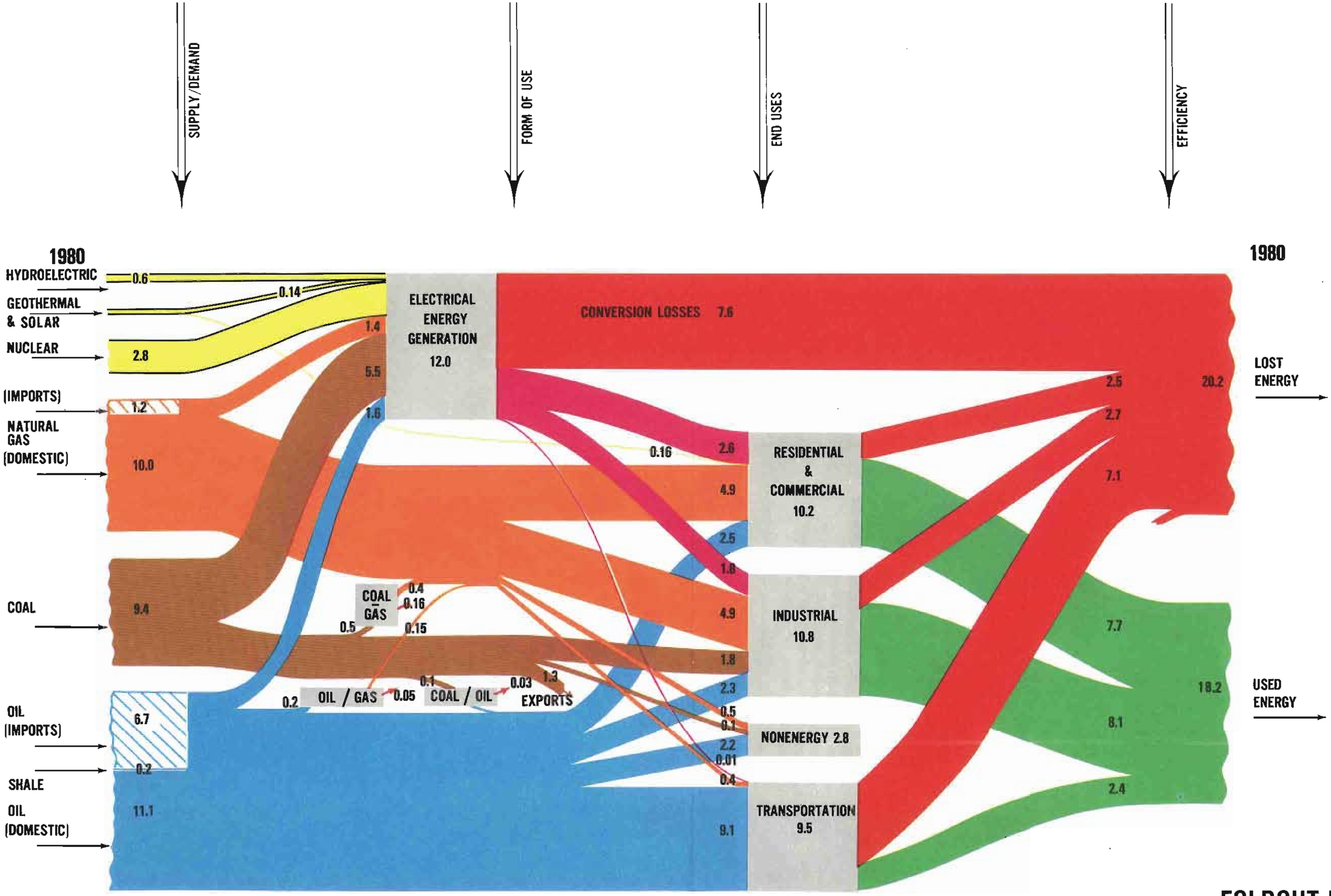
C


SUPPLY/DEMAND
FORM OF USE
END USES
EFFICIENCY
1970
1970
HYDROELECTRIC
GEOTHERMAL
NUCLEAR
(IMPORTS)
NATURAL
GAS
(DOMESTIC)
COAL
OIL
(IMPORTS)
OIL
(DOMESTIC)
0.4
0.003
0.1
0.4
10.3
7.4
3.5
10.4
1.9
3.7
1.0
ELECTRICAL
ENERGY
GENERATION
7.1
EXPORTS 0.9
CONVERSION LOSSES
4.6
1.3
3.5
0.2
2.5
1.2
4.6
2.5
1.6
0.3
0.1
1.5
0.007
0.3
7.4
RESIDENTIAL
&
COMMERCIAL
7.5
INDUSTRIAL
9.9
NONENERGY 1.9
TRANSPORTATION
7.7
1.9
2.4
5.8
14.7
5.6
7.4
1.9
15.0
LOST
ENERGY
USED
ENERGY

FOLDOUT C

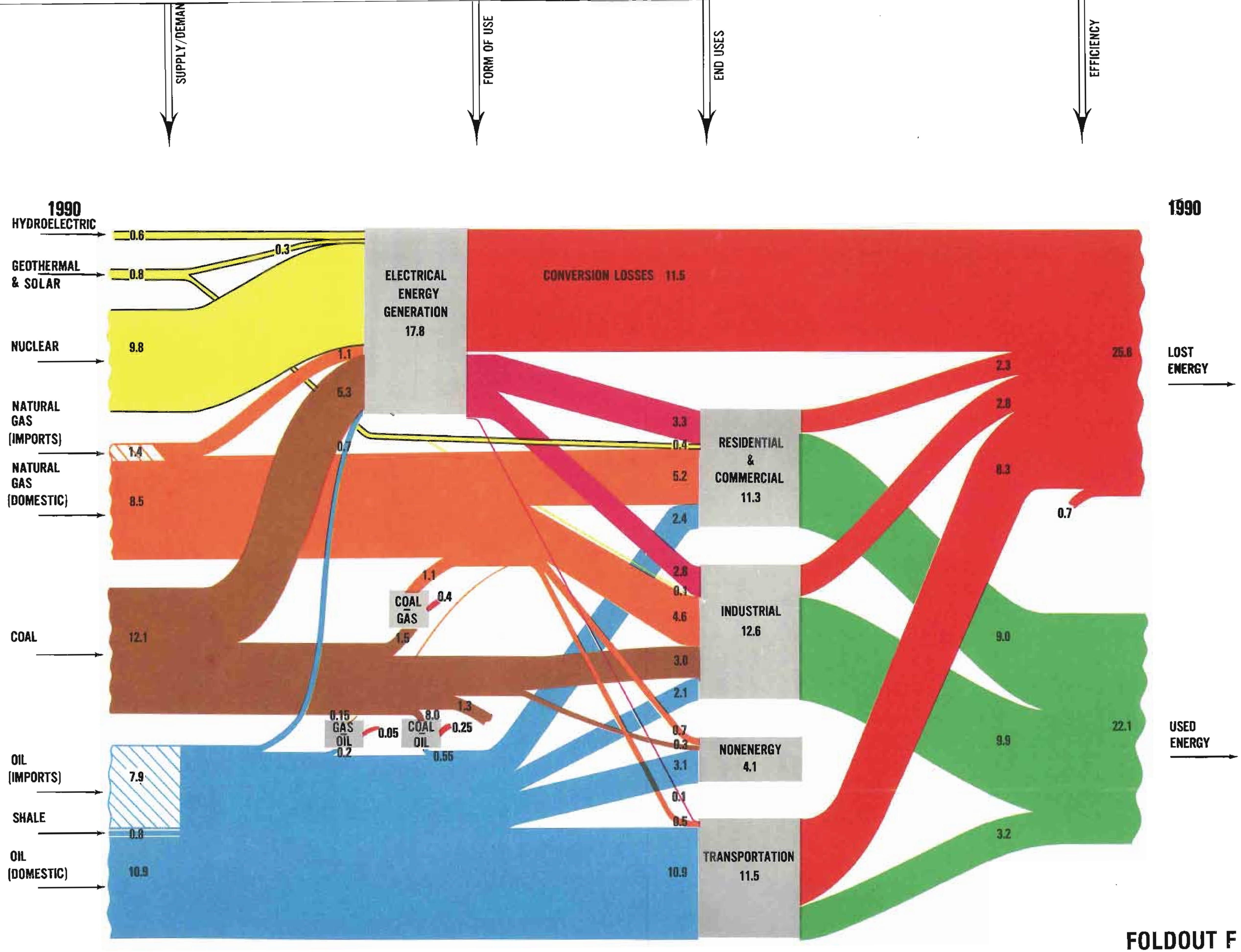

SUPPLY/DEMAND
FORM OF USE
END USES
EFFICIENCY
1975
HYDROELECTRIC
0.5
GEOTHERMAL
0.02
NUCLEAR
0.8
NATURAL GAS (IMPORTS)
0.4
NATURAL GAS (DOMESTIC)
9.1
COAL
7.1
OIL (IMPORTS)
6.0
OIL (DOMESTIC)
9.4
1.5
4.1
1.6
ELECTRICAL ENERGY GENERATION 8.5
CONVERSION LOSSES
5.4
0.8
EXPORTS
1.8
3.5
0.1
2.2
1.3
3.9
2.0
1.7
0.3
0.1
1.6
0.01
0.3
0.01
8.4
RESIDENTIAL & COMMERCIAL 7.6
INDUSTRIAL 8.9
NONENERGY 2.0
TRANSPORTATION 8.7
1.9
2.2
8.6
5.7
6.7
2.2
1975
16.0
LOST ENERGY
14.6
USED ENERGY

FOLDOUT D


SUPPLY/DEMAND
FORM OF USE
END USES
EFFICIENCY
1980
HYDROELECTRIC
0.6
0.14
GEOTHERMAL & SOLAR
NUCLEAR
2.8
1.4
5.5
1.6
(IMPORTS)
1.2
NATURAL GAS (DOMESTIC)
10.0
COAL
9.4
OIL (IMPORTS)
6.7
0.2
SHALE
OIL (DOMESTIC)
11.1
ELECTRICAL ENERGY GENERATION 12.0
CONVERSION LOSSES 7.6
COAL GAS
0.4
0.16
0.5
0.15
0.2
OIL / GAS
0.05
0.1
COAL / OIL
0.03
1.3
EXPORTS
0.16
2.6
4.9
2.5
1.8
4.9
1.8
2.3
0.5
0.1
2.2
0.01
0.4
9.1
RESIDENTIAL & COMMERCIAL 10.2
INDUSTRIAL 10.8
NONENERGY 2.8
TRANSPORTATION 9.5
2.5
2.7
7.1
7.7
8.1
2.4
1980
20.2
LOST ENERGY
18.2
USED ENERGY

E

FOLDOUT E

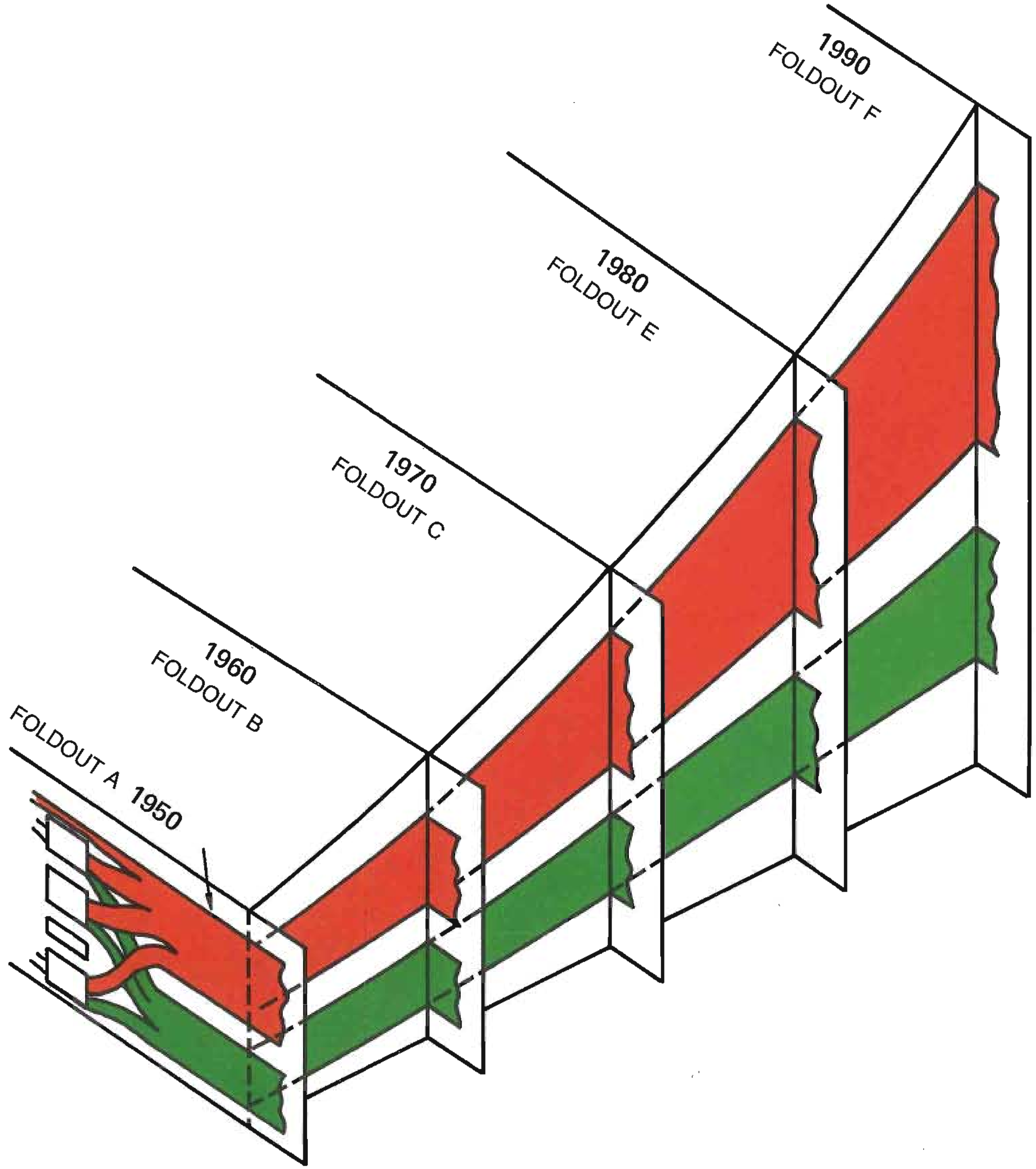


SUPPLY/DEMAND
FORM OF USE
END USES
EFFICIENCY
1990
HYDROELECTRIC
0.6
0.3
GEOTHERMAL & SOLAR
0.8
NUCLEAR
9.8
NATURAL GAS (IMPORTS)
1.4
NATURAL GAS (DOMESTIC)
8.5
COAL
12.1
OIL (IMPORTS)
7.9
SHALE
0.8
OIL (DOMESTIC)
10.9
ELECTRICAL ENERGY GENERATION 17.8
1.1
5.3
0.7
COAL GAS
0.4
1.1
1.5
GAS OIL
0.15
0.05
0.2
COAL OIL
8.0
0.25
1.3
0.55
CONVERSION LOSSES 11.5
3.3
0.4
5.2
2.4
2.6
0.1
4.6
3.0
2.1
0.7
0.3
3.1
0.1
0.5
10.9
RESIDENTIAL & COMMERCIAL 11.3
INDUSTRIAL 12.6
NONENERGY 4.1
TRANSPORTATION 11.5
2.3
2.8
8.3
9.0
9.9
3.2
0.7
25.8
22.1
1990
LOST ENERGY
USED ENERGY

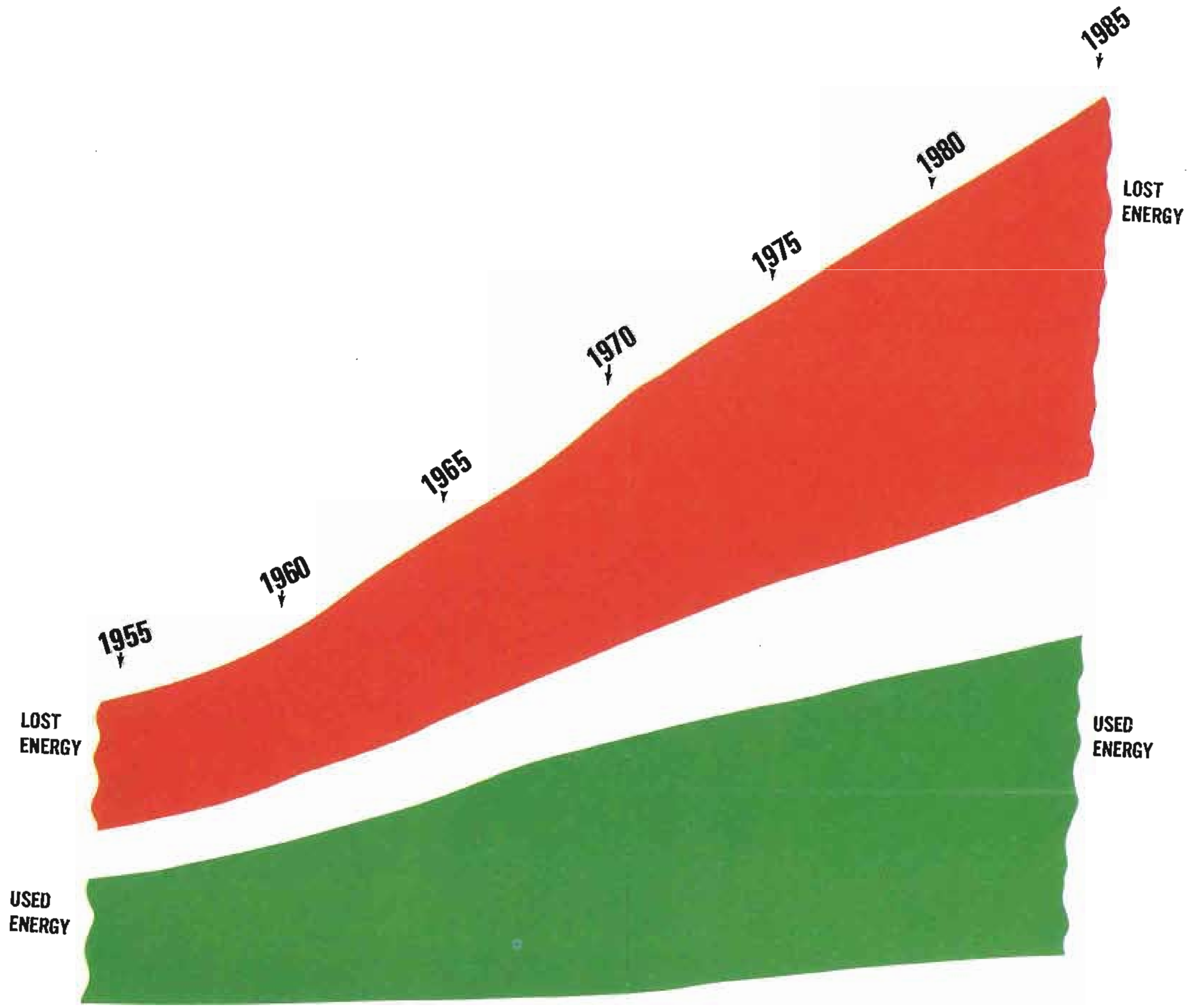
F

FOLDOUT F

CONSTRUCTION OF CROSS PLOTS (EFFICIENCY PLOT SHOWN)

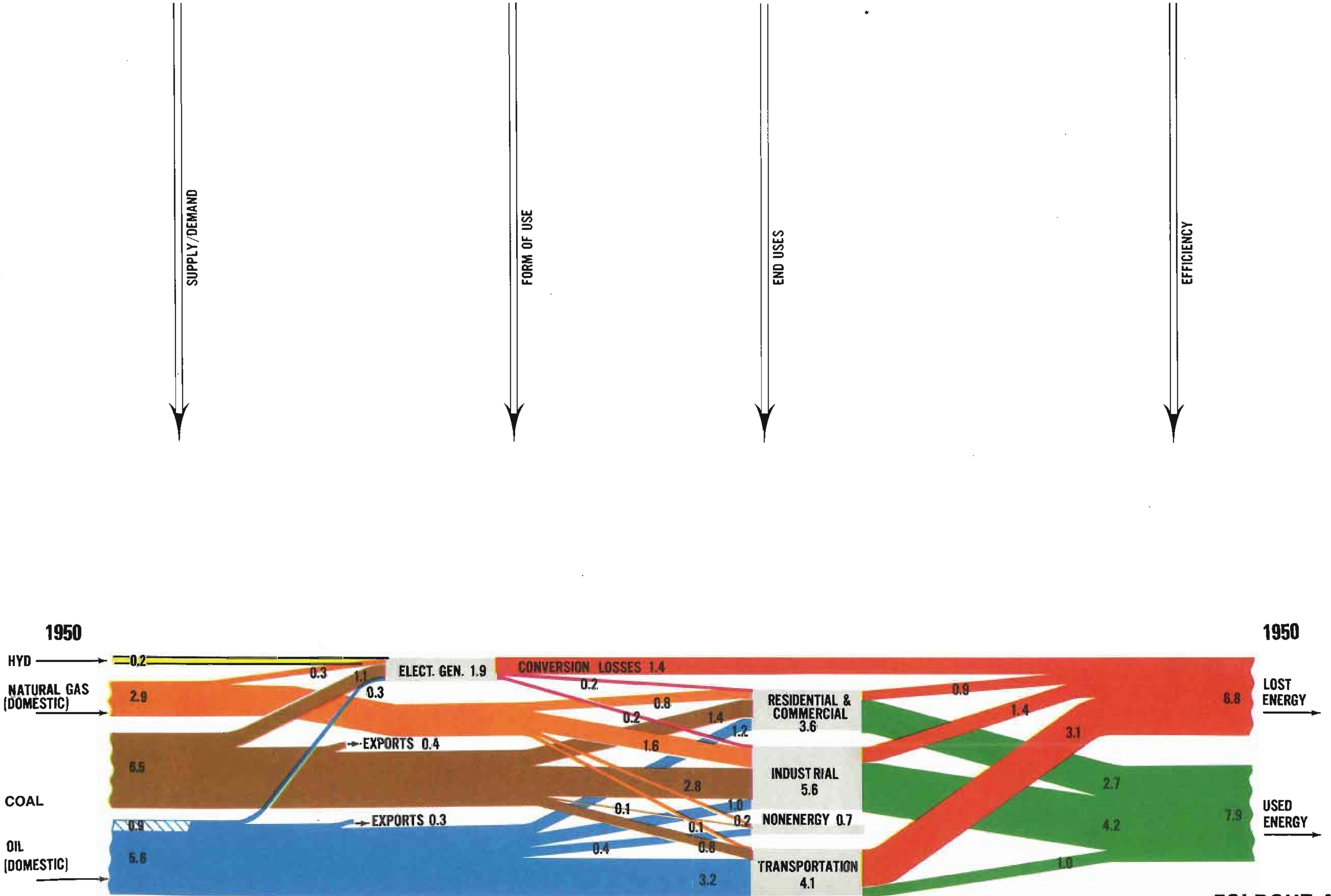


G


1985
1980
1975
1970
1965
1960
1955
LOST ENERGY
USED ENERGY
LOST ENERGY
USED ENERGY

H

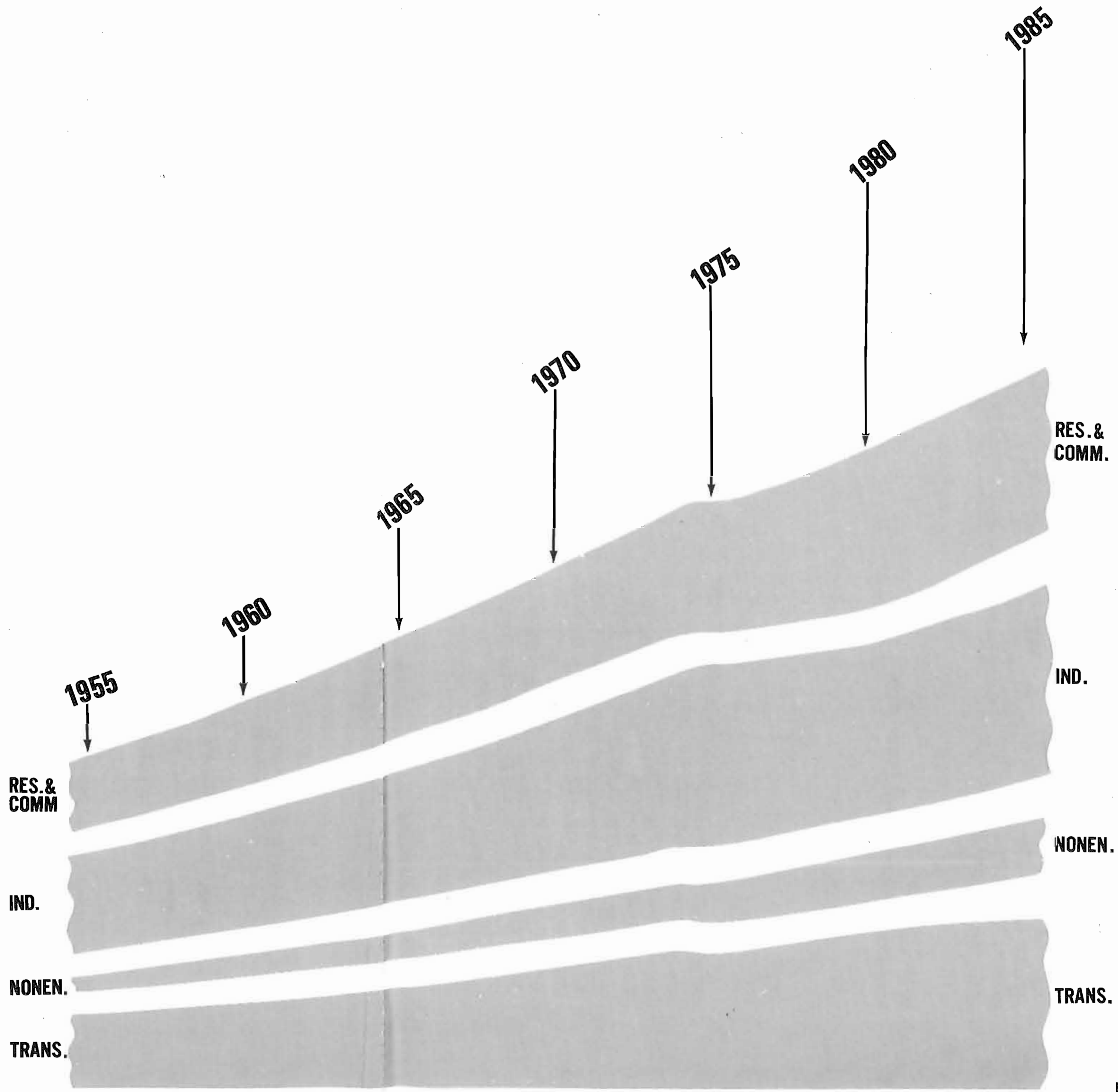
A



SUPPLY/DEMAND
FORM OF USE
END USES
EFFICIENCY
1950
1950
HYD
0.2
NATURAL GAS (DOMESTIC)
2.9
COAL
6.5
0.9
OIL (DOMESTIC)
5.6
0.3
1.1
0.3
ELECT. GEN. 1.9
CONVERSION LOSSES 1.4
0.2
0.8
0.2
1.4
1.2
1.6
EXPORTS 0.4
EXPORTS 0.3
2.8
1.0
0.1
0.1
0.2
0.4
0.8
3.2
RESIDENTIAL & COMMERCIAL 3.6
INDUSTRIAL 5.6
NONENERGY 0.7
TRANSPORTATION 4.1
0.9
1.4
3.1
2.7
4.2
1.0
6.8
7.9
LOST ENERGY
USED ENERGY

FOLDOUT A

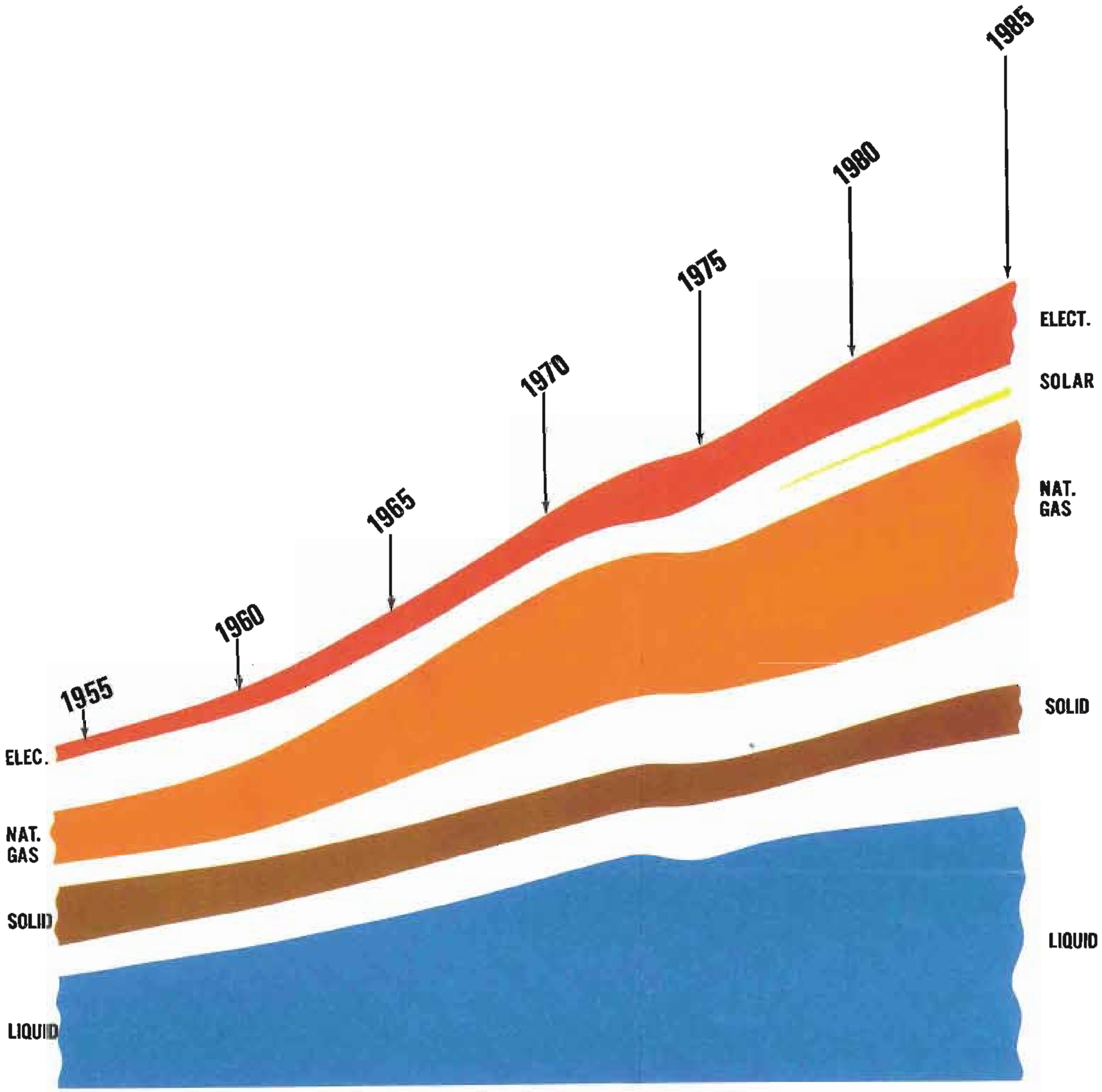
END USES



I

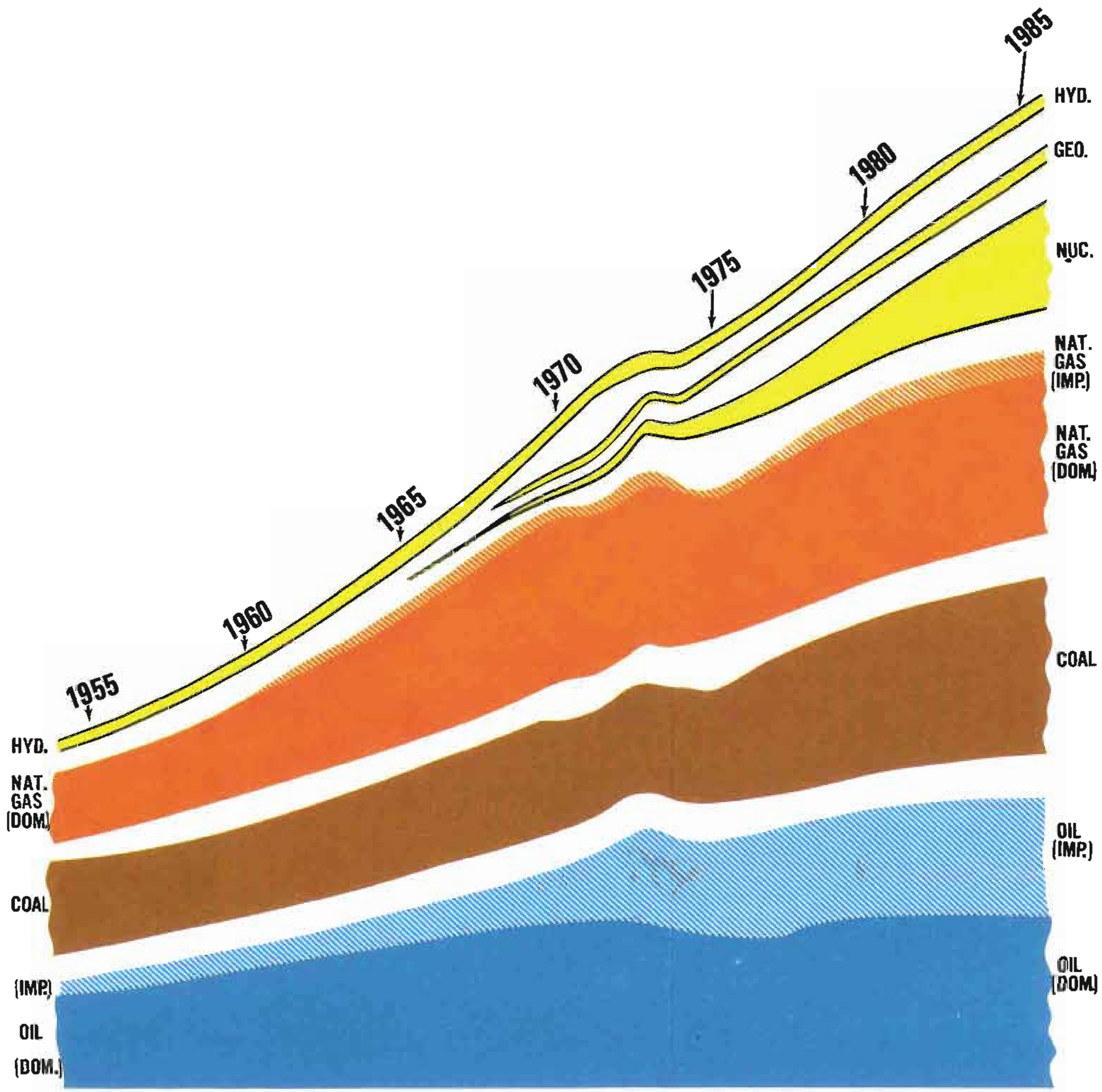
FOLDOUT I

FORM OF USE



1955
1960
1965
1970
1975
1980
1985
ELEC.
NAT. GAS
SOLID
LIQUID
ELECT.
SOLAR
NAT. GAS
SOLID
LIQUID

J


1955
1960
1965
1970
1975
1980
1985
HYD.
NAT.
GAS
(DOM.)
COAL
(IMP.)
OIL
(DOM.)
HYD.
GEO.
NUC.
NAT.
GAS
(IMP.)
NAT.
GAS
(DOM.)
COAL
OIL
(IMP.)
OIL
(DOM.)

K

CHART 2

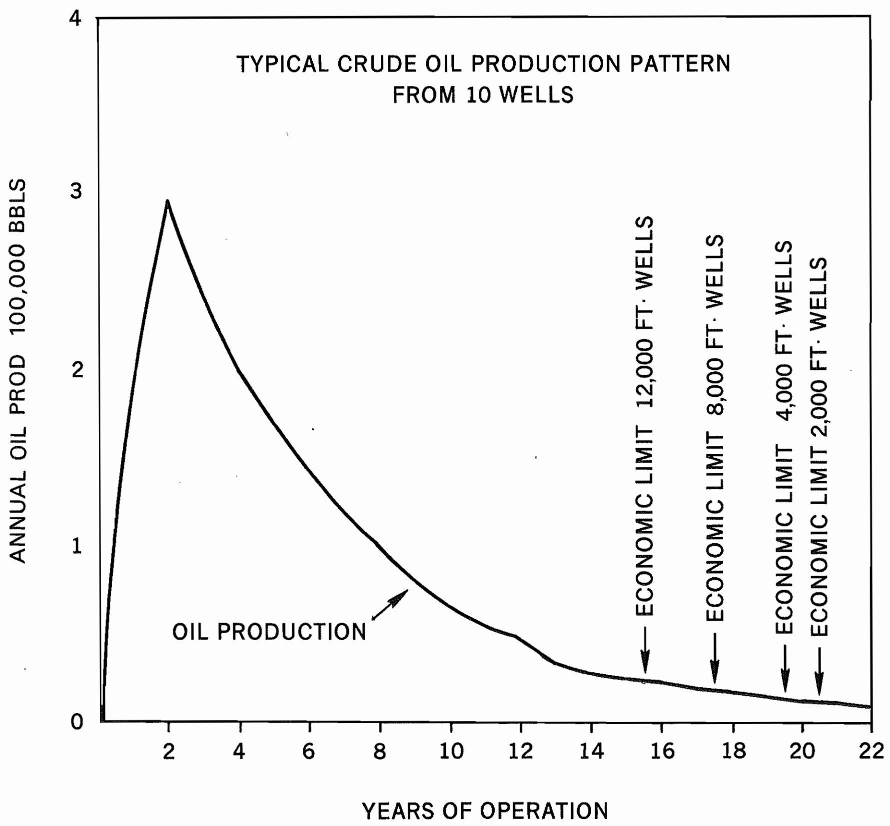
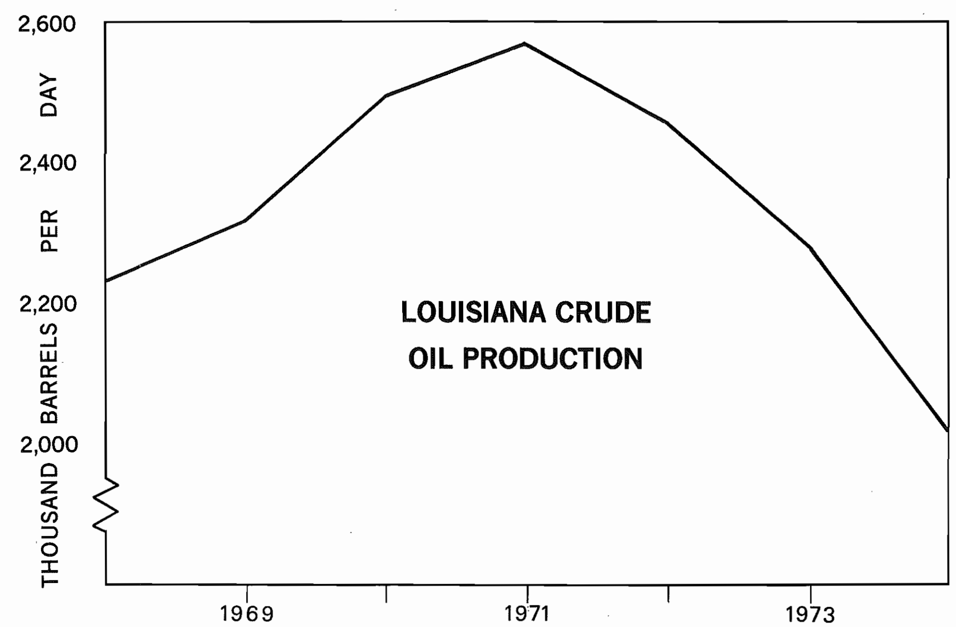
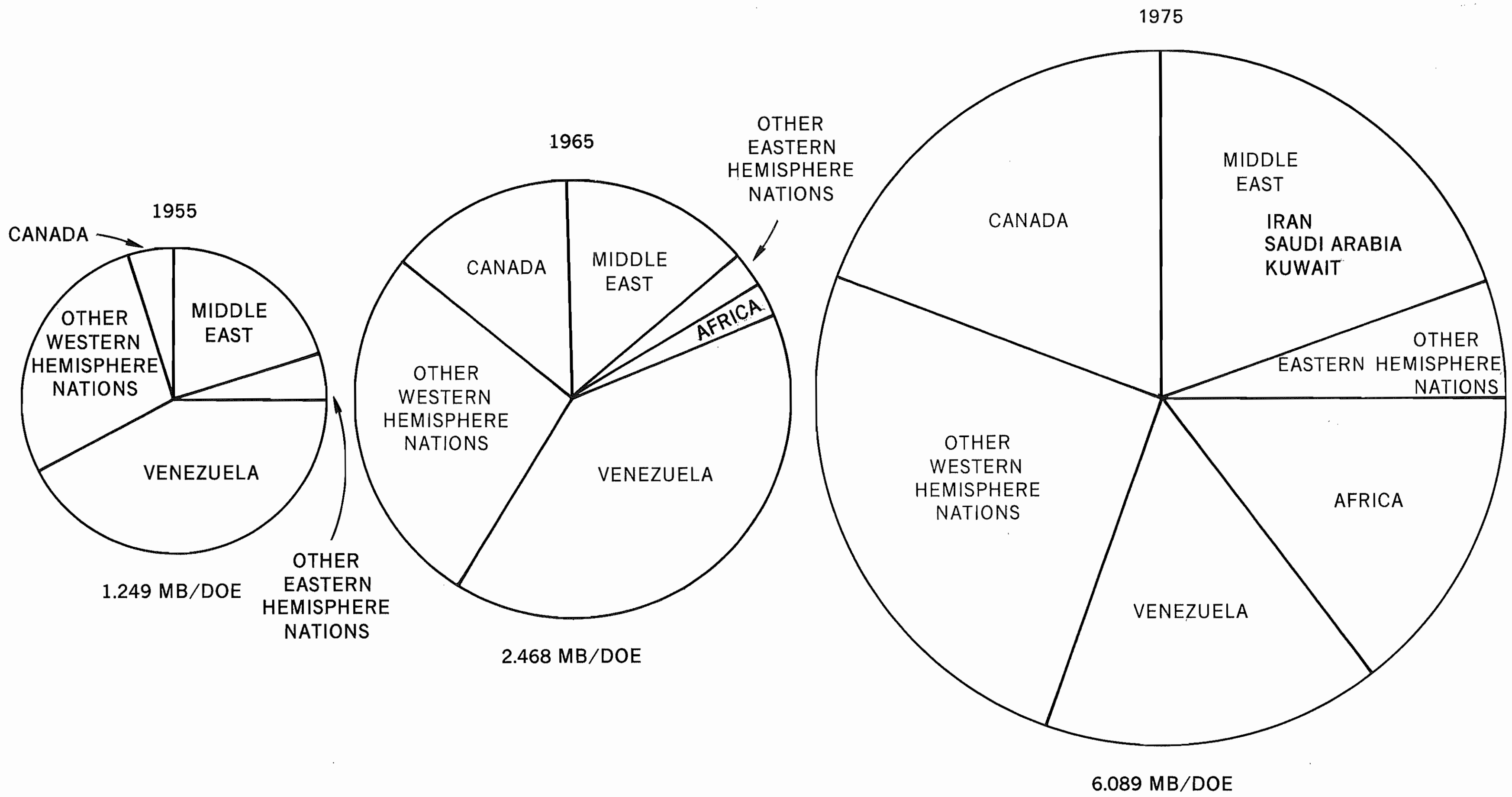


CHART 1



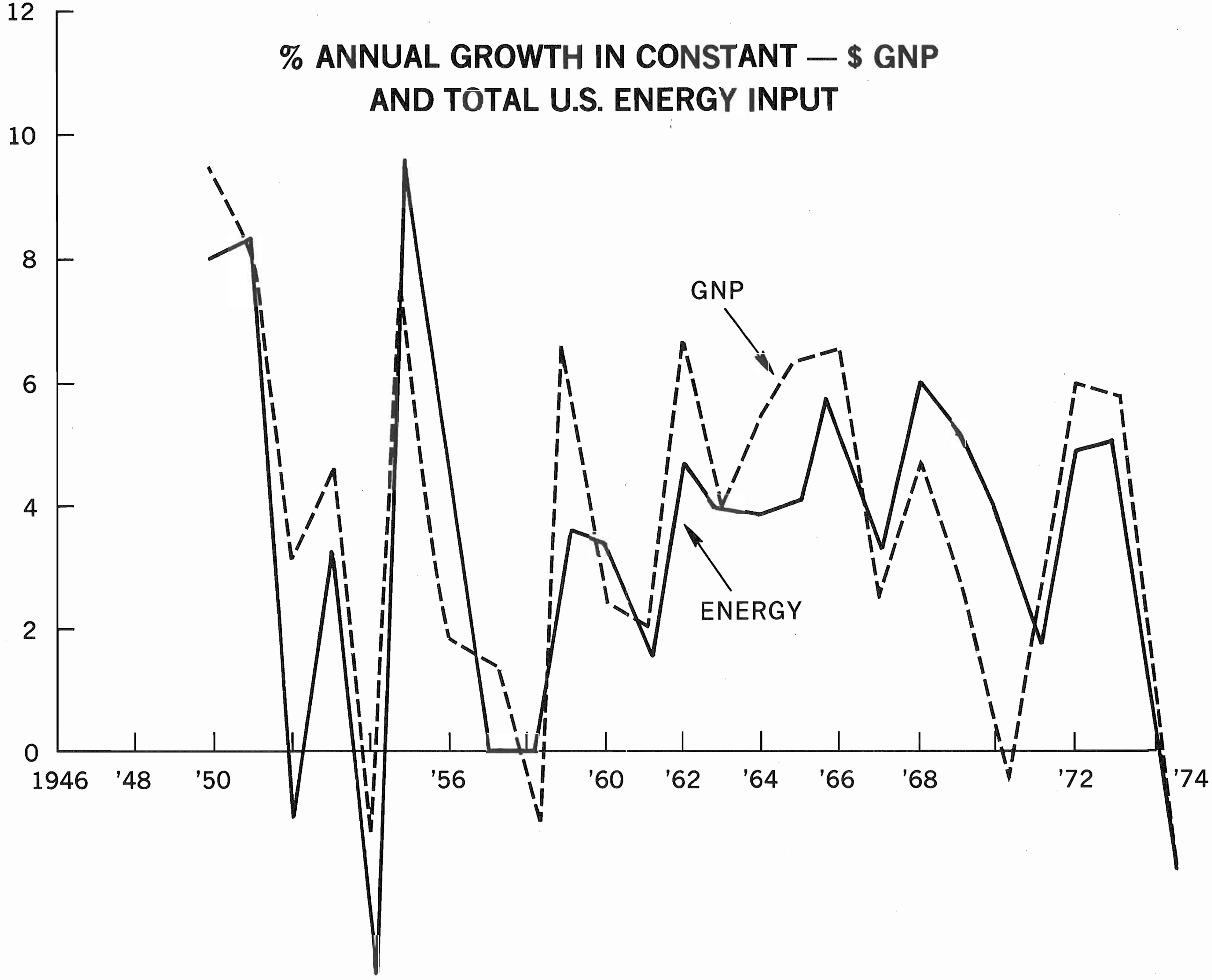
FOLDOUT L

GEOGRAPHIC ORIGIN OF U.S. TOTAL PETROLEUM IMPORTS



M

FOLDOUT M

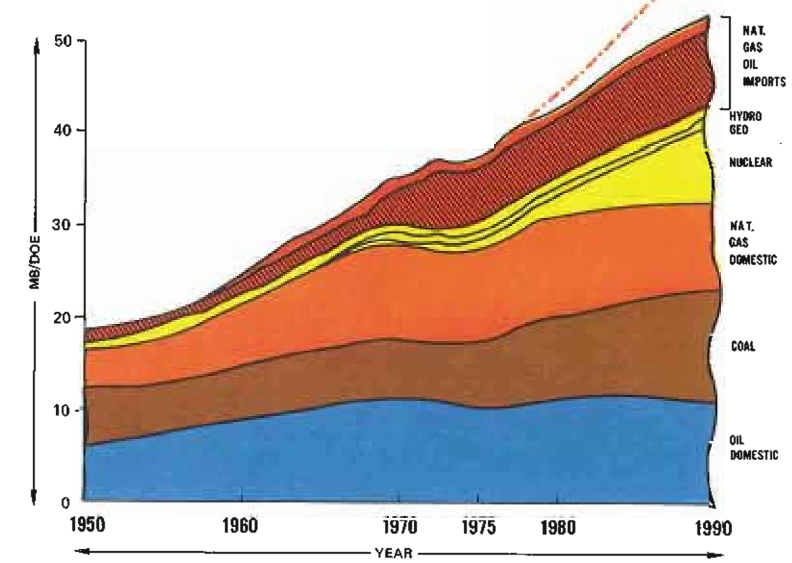


% ANNUAL GROWTH IN CONSTANT — $ GNP
AND TOTAL U.S. ENERGY INPUT
12
10
8
6
4
2
0
1946
'48
'50
'56
'60
'62
'64
'66
'68
'72
'74
GNP
ENERGY

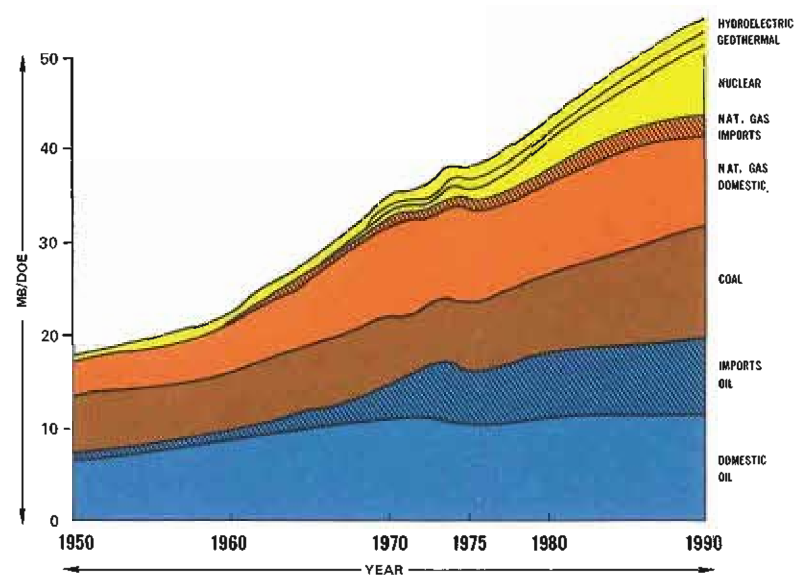
N

FOLDOUT N

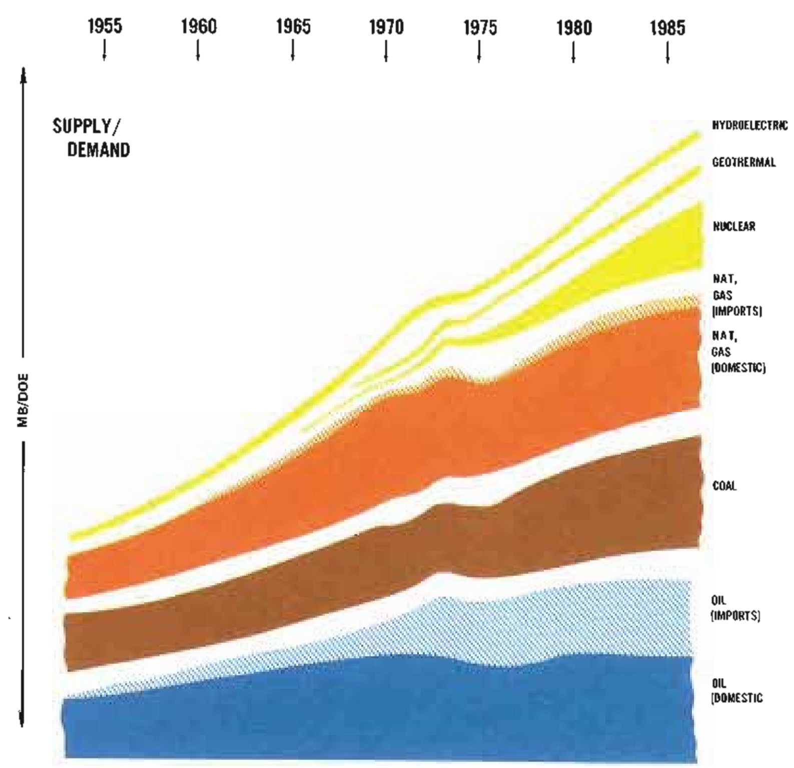
STEP 3



STEP 2



STEP 1



SUPPLY/DEMAND
(1900 - 2050)
MB/D OIL EQUIVALENT vs YEARS