SWP489

# Global Energy Prospects

World Bank Staff Working Paper No. 489

August 1981

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A Background Study to World Development Report 1981

This paper presents the assumptions and discusses some of the key issues that underlie the energy projections contained in the World Development Report 1981. It examines the adjustments which have taken place since the oil price increase in 1973/74 in the use of energy in five major country groups. Based on these trends in energy conservation and increased energy efficiency, as well as on assumptions about income levels and a 3 percent a year increase in real energy prices, the paper provides energy projections by major fuels for these country groupings for the 1980s. It also examines the supply prospects of the four major fuels--petroleum, natural gas, coal, and primary electricity--and those of synthetic fuels.

The paper concludes that the transition from petroleum to other fuels will extend well beyond the current decade. Oil is projected to provide 40 percent of the world's energy needs by 1990. During this decade, coal appears to have the greatest potential to satisfy energy demand and to be used as a substitute for oil, mainly in industrial countries. The oil-importing developing countries, despite their extensive hydroelectric potential and coal reserves, will continue to rely heavily on oil imports to meet their rapidly growing energy demands.

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ACKNOWLEDGMENTS

This paper grew out of our efforts to provide background information and projections for the energy chapter of the World Development Report 1981. We have benefited greatly from the advice and support of many people inside and outside the World Bank. We are particularly indebted to Hollis Chenery, Helen Hughes, Shamsher Singh, Enzo Grilli, Vinod Dubey, Christine Wallich, and Turgay Ozkan for their valuable comments and suggestions on earlier drafts of this paper. We are also very grateful to Robert Sadove, John Strongman, and Matthew Mitchell for their assistance in obtaining detailed country supply projections for the major fuels.

We would like to thank Razi Amin for his assistance in the research for this paper, as well as in the use of computers; Whitney Watriss and Jim McEuen for their editorial help; and Debbie Kreamer for her expert and patient typing of too many drafts.

The views expressed in this paper are ours, as is the responsibility for any omissions and errors.

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| b/d | Barrels per day |
| BTU | British thermal unit(s) |
| CMEA | Council for Mutual Economic Assistance (also COMECON) |
| EEC | European Economic Community |
| GW | Gigawatt(s) |
| IEA | International Energy Agency |
| mbd | Million barrels per day |
| mbdoe | Million barrels per day of oil equivalent |
| NGL | Natural gas liquids |
| OECD | Organisation for Economic Co-operation and Development |
| OPEC | Organization of Oil-Exporting Countries |
| tce | Tons of coal equivalent |
| UAE | United Arab Emirates |
| UN | United Nations |
| WDR IV | World Development Report 1981 |
| WOCOL | World Coal Study (Massachusetts Institute of Technology) |

## INTRODUCTION

The world economy is currently in a period of transition with respect to energy usage, with a shift from petroleum-based fuels to alternate energy sources. This phenomenon is not new. There have been two earlier energy transitions--one from wood to coal and the second from coal to petroleum and natural gas. Until the latter part of the 19th century, the main source of energy had been biomass (mainly wood). It was first replaced by coal during a period that extended into the mid-1940s, and later by oil and natural gas. Currently, the last two fuels account for almost 70 percent of world energy consumption.

There is a fundamental difference between the previous energy transitions and the one the world economy is now facing. In past transitions, new energy sources, combined with new technologies for using them, opened up opportunities for new economic activities. In the current transition, however, the focus is on substituting one source for another, that is, mainly on developing substitute energy sources to replace oil. 1/

During the 1970s, petroleum prices (in real terms) increased almost fivefold. 2/ These increases were not gradual but came in two distinct jolts (1973/74 and 1979/80) which had a deep and lasting impact on the world energy economy. In this paper the focus is on the changes that have taken place in this economy since the first major petroleum price increase in 1973. Conclusions are drawn, based on observed adjustments to the higher energy prices, about the likely global trends in the demand and supply for energy during the 1980s.

This paper provides demand and supply projections for the four major fuels--petroleum, natural gas, solid fuels (mainly coal), and primary electric-

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1/ Wallace E. Tyner, "Our Energy Transition: The Next Twenty Years," American Journal of Agricultural Economics, Vol. 62, No. 5, December 1980, p. 957.

2/ This price increase refers to the average Organization of Petroleum-Exporting Countries (OPEC) price for petroleum. Although petroleum exports from OPEC represent only about one-fourth of the world's primary energy supplies, OPEC decisions percolate through energy markets.

ity (i.e., electricity from hydro, nuclear, and geothermal resources)--in five major country groups: industrialized, centrally planned economies, capital-surplus oil-exporting, net oil-exporting developing, and net oil-importing developing.

Section I provides an overview of the major trends that will dominate the development in the world energy economy during the 1980s. Sections II and III focus, respectively, on the trends and issues of energy demand and supplies. Finally, Section IV discusses our assumptions about energy prices and the key factors that will determine them.

# I. OVERVIEW OF GLOBAL ENERGY PROSPECTS

## A. The Demand for Energy

Globally, the demand for energy is expected to increase during the 1980s at a much slower pace (3.2 percent a year) than during the 1960s (5.2 percent) and the early 1970s (3.5 percent) (Table 1). Several factors account for this. First, the economies of both industrial and developing countries are projected to grow more slowly during the 1980s than during the previous two decades. 1/ Second, the increases in energy prices already have had, and will continue to have, a dampening effect on the growth of energy demand.

Although it is still too early to evaluate the full impact that energy prices will have on demand, 2/ the evidence available seems to indicate that thus far the effect, as a percentage of total energy consumption, was somewhat larger in industrial countries as compared with other regions. Chart I shows the impact in terms of the energy savings that have occurred since

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1/ The following table summarizes the past and projected economic growth (in terms of GNP) of the five country groups since 1960:

| Country Group | 1960-70 | 1970-80 | 1980-90 |
|---|---|---|---|
| | (annual average percent) | | |
| Industrialized | 5.1 | 3.3 | 3.6 |
| Centrally Planned Economies | 4.0* | 4.8* | 3.9 |
| Capital-Surplus Oil Exporting | 10.5 | 7.2 | 5.5 |
| Net Oil-Exporting | 6.5 | 5.2 | 6.5 |
| Net Oil-Importing | 5.7 | 5.1 | 5.4 |

* Estimated.

Source: World Development Report, 1981, high case.

2/ The demand for energy depends, among other factors, on the energy efficiency of the existing capital stock. Some capital goods have an economic life span of more than fifty years. Replacing them with more energy efficient capital usually takes a long time. Hence, demand responds to an increase of energy prices with growing intensity as time goes by; this intensity eventually tapers off when no more capital goods are being replaced.

**Table 1:** COMMERCIAL PRIMARY ENERGY PRODUCTION AND CONSUMPTION, BY COUNTRY GROUP, 1970-1990

(mbd)

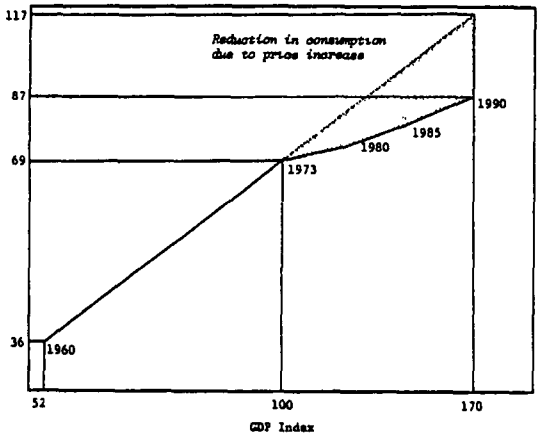
| Country Group | 1970 | | 1978 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|
| | Production | Consumption | Production | Consumption | Production | Consumption | Production | Consumption |
| Industrial Countries | 43.2 | 60.6 | 46.9 | 70.3 | 50.6 | 72.4 | 64.3 | 87.0 |
| Petroleum | 12.7 | 29.9 | 13.3 | 35.3 | 14.5 | 35.0 | 16.4 | 37.4 |
| Natural Gas | 13.0 | 12.8 | 14.1 | 14.9 | 13.8 | 15.0 | 13.2 | 16.2 |
| Solid Fuels | 13.0 | 13.3 | 12.4 | 13.1 | 13.9 | 14.0 | 20.4 | 19.1 |
| Primary Electricity | 4.5 | 4.6 | 7.1 | 7.1 | 8.4 | 8.4 | 14.3 | 14.3 |
| Centrally Planned Economies | 28.8 | 27.6 | 44.0 | 41.6 | 45.2 | 43.0 | 63.4 | 62.1 |
| Petroleum | 8.0 | 7.2 | 14.3 | 12.7 | 13.7 | 13.1 | 17.9 | 17.3 |
| Natural Gas | 3.8 | 3.8 | 7.0 | 6.9 | 7.7 | 7.0 | 12.6 | 12.3 |
| Solid Fuels | 16.1 | 15.7 | 21.1 | 20.5 | 21.8 | 20.9 | 29.8 | 29.4 |
| Primary Electricity | 0.9 | 0.9 | 1.6 | 1.6 | 2.0 | 2.0 | 3.1 | 3.1 |
| Capital-Surplus Oil-Exporting Countries | 12.8 | 0.3 | 17.5 | 0.7 | 18.6 | 0.9 | 21.7 | 1.7 |
| Petroleum | 12.7 | 0.2 | 17.3 | 0.5 | 18.3 | 0.7 | 20.4 | 1.1 |
| Natural Gas | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 1.3 | 0.6 |
| Solid Fuels | - | - | - | - | - | - | - | - |
| Primary Electricity | - | - | - | - | - | - | - | - |
| Net Oil Exporters | 13.7 | 2.8 | 18.1 | 5.0 | 16.7 | 5.5 | 25.2 | 10.0 |
| Petroleum | 12.7 | 1.8 | 15.9 | 3.3 | 14.2 | 3.6 | 18.3 | 5.5 |
| Natural Gas | 0.7 | 0.7 | 1.7 | 1.2 | 2.0 | 1.4 | 5.9 | 3.5 |
| Solid Fuels | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.3 | 0.3 |
| Primary Electricity | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.7 | 0.7 |
| Net Oil Importers | 4.7 | 7.8 | 6.8 | 13.2 | 7.5 | 13.7 | 15.1 | 24.3 |
| Petroleum | 1.2 | 4.2 | 1.2 | 7.3 | 1.5 | 7.3 | 2.8 | 11.2 |
| Natural Gas | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.7 | 1.6 | 1.6 |
| Solid Fuels | 2.3 | 2.4 | 3.3 | 3.6 | 3.5 | 3.7 | 5.6 | 6.4 |
| Primary Electricity | 0.9 | 0.9 | 1.8 | 1.8 | 2.0 | 2.0 | 5.1 | 5.1 |
| Bunkers | | 2.9 | | 2.8 | | 3.1 | | 4.6 |
| Total | 103.2 | 99.1 | 133.3 | 130.9 | 138.6 | 135.5 | 189.7 | 185.1 |
| Petroleum | 47.3 | 43.3 | 62.0 | 59.1 | 62.2 | 59.7 | 75.8 | 72.5 |
| Natural Gas | 17.9 | 17.7 | 23.6 | 23.6 | 24.3 | 24.3 | 34.6 | 34.2 |
| Solid Fuels | 31.5 | 31.5 | 36.9 | 37.3 | 39.3 | 38.7 | 56.1 | 55.2 |
| Primary Electricity | 6.5 | 6.6 | 10.8 | 10.9 | 12.8 | 12.8 | 23.2 | 23.2 |

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22); World Bank projections.

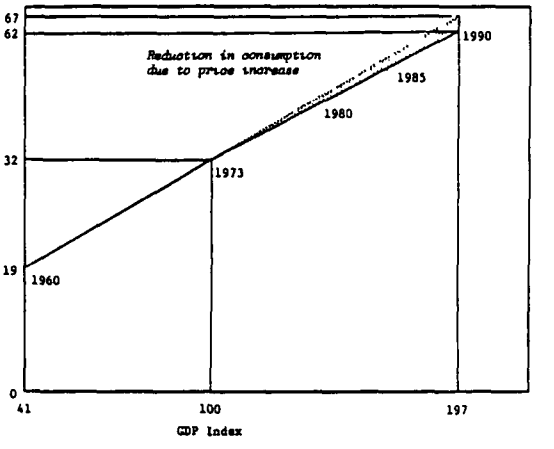
Chart I: EFFECTS OF INCOME AND PRICE ON ENERGY CONSUMPTION BY COUNTRY GROUP, 1960-90

(mbdoe)

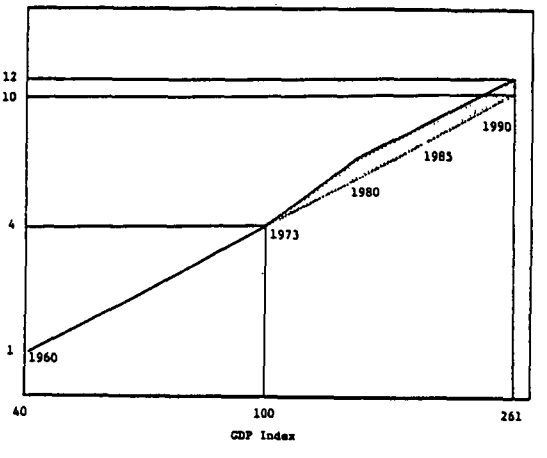
Industrialized Countries



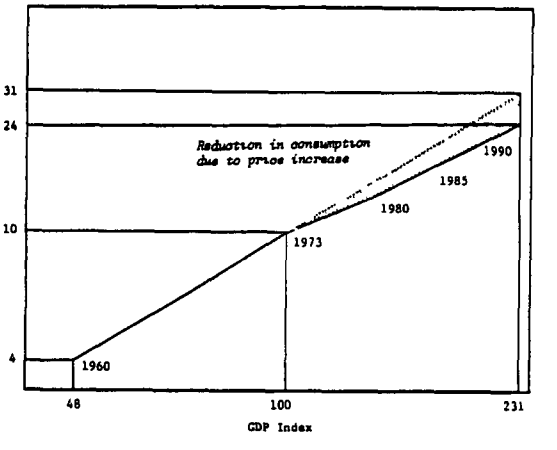

Centrally Planned Economies




Oil-Exporting Developing Countries




Oil-Importing Developing Countries



1973 and the possible effects of the projected increase in energy prices for four major regions. The charts for the individual regions clearly demonstrate the powerful effect of energy pricing policies: energy savings so far have been greatest in those regions where domestic energy prices were more completely adjusted to world market levels. 1/

The industrial countries currently consume more than half of the world's commercial energy output. 2/ Chart II shows the consumption of major fuels in the five regions for the year 1980. (Note that the size of the pies in this chart reflects the quantity of energy consumed.) With the exception of the centrally planned economies, petroleum is still the single most important source of energy. More than half of the world's oil output is consumed in industrial countries. The trend in energy demand in these countries will therefore play a key role in the evolution of international oil markets in the 1980s. Not only will the economic growth of these countries and the energy pricing policies they adopt determine the potential for further energy savings during the 1980s, but public and private investment in alternative fuels will determine to what extent they will remain dependent on oil imports. 3/ Most observers of the international oil markets agree that the industrial countries will have to rely for their oil imports on supplies from the major oil-producing countries in the Middle East, and there is little doubt that the supply situation will remain highly volatile during the 1980s.

The energy projections in this paper point to considerable improvements in the efficiency of energy use and to a gradual reduction in the share of conventional oil during the 1980s (Chart III). While the shares of individual fuels to total energy consumption are not expected to change

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1/ The price of energy is only one of several factors that determine the demand for energy. Among all these factors, however, price appears to have the strongest impact on the use of energy per unit of GDP.

2/ In this report the term "commercial energy" refers to a composite of the four major fuels: petroleum, natural gas, solid fuels (coal), and primary electricity. Excluded are many of the "traditional" fuels used in developing countries--such as wood, dung, and charcoal--which are also frequently traded commercially.

3/ A worsening of the economic conditions during the 1980s might further delay the investments required to curb the demand for oil.

Chart II: COMMERCIAL PRIMARY ENERGY CONSUMPTION BY COUNTRY GROUP, 1980

(mbd)

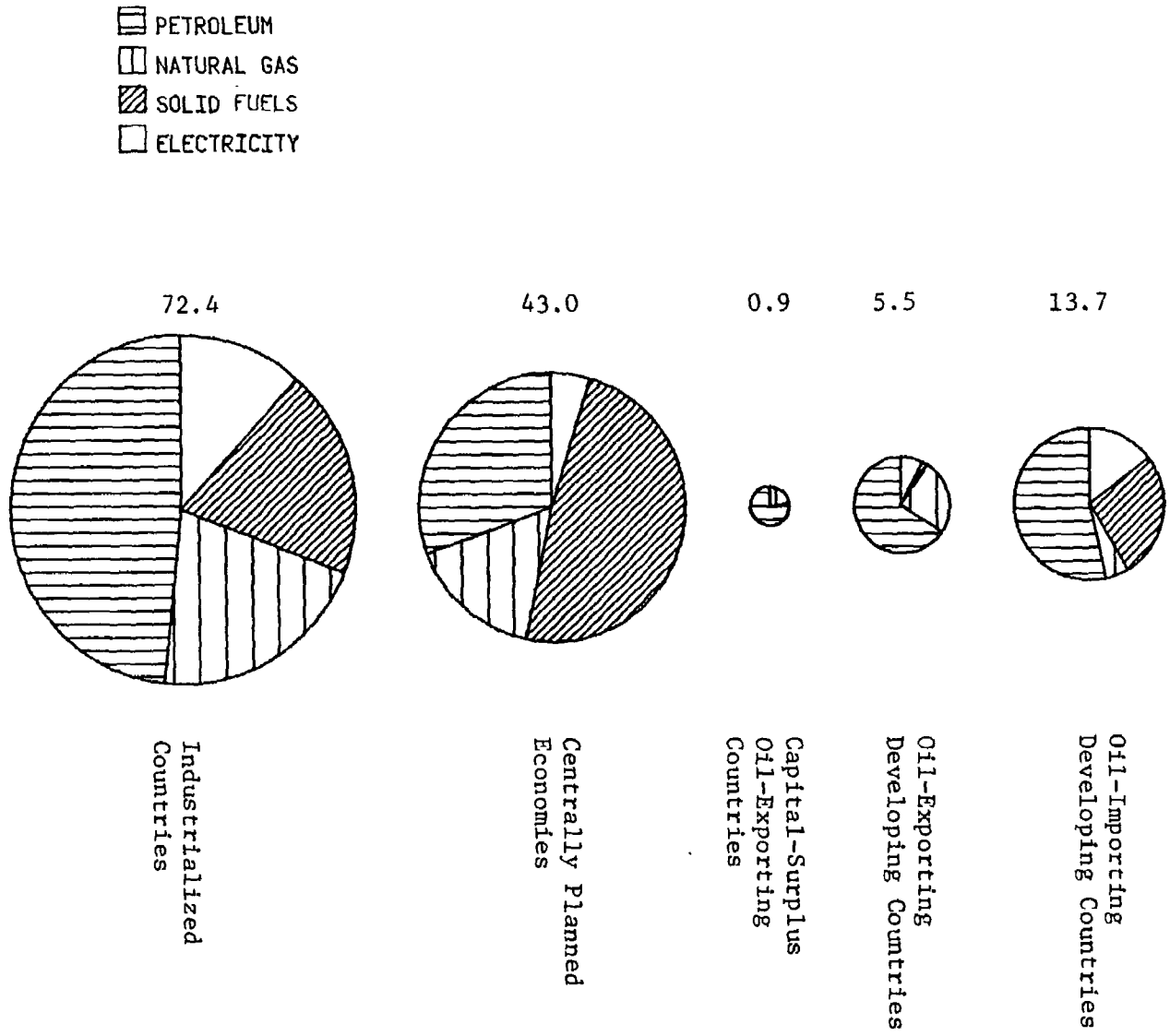
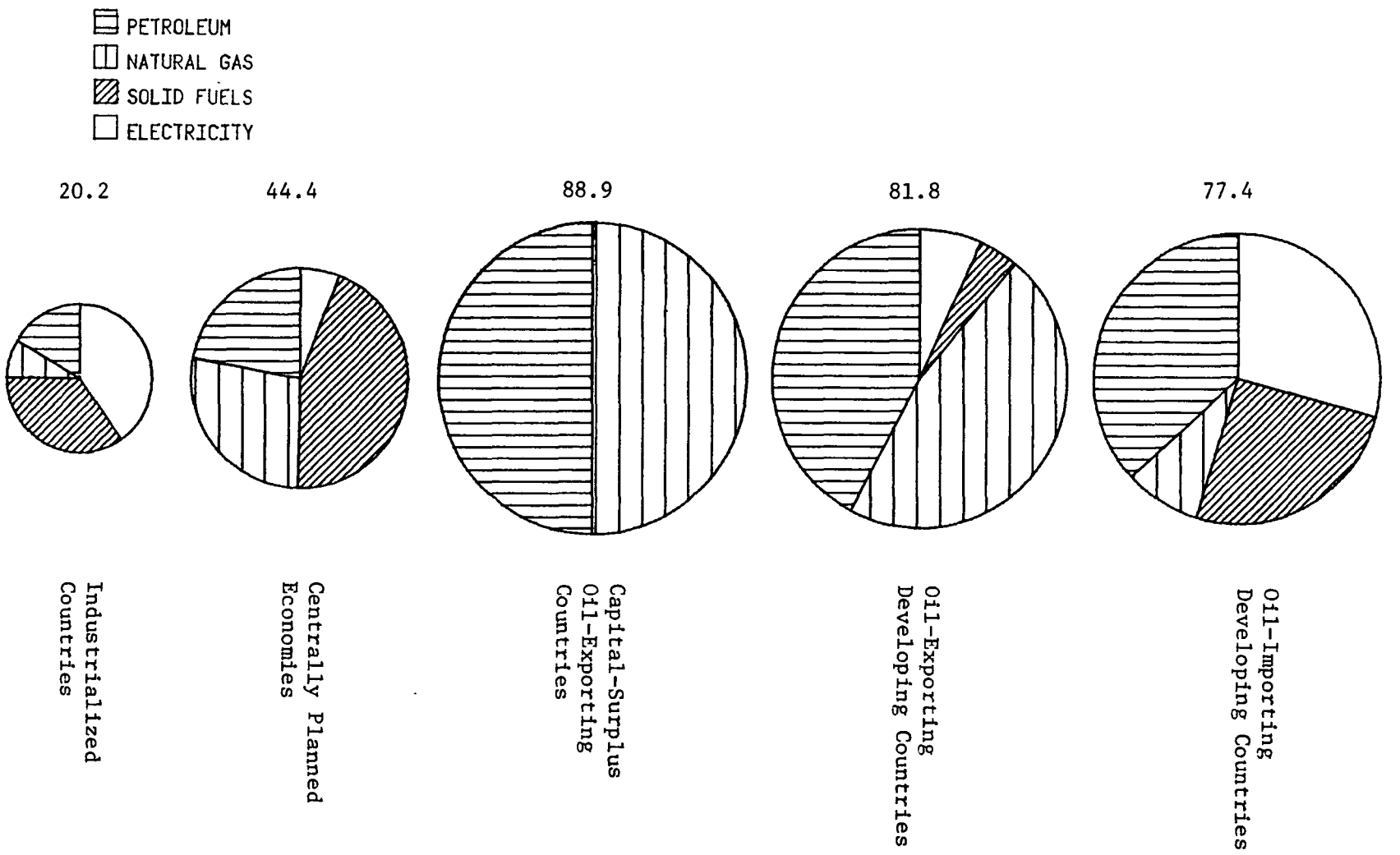


Chart III: PROJECTED INCREMENTAL WORLD ENERGY CONSUMPTION BY COUNTRY GROUP, 1980-90

(Percentage Total Relative Increase)



drastically during this decade, the recent increases in petroleum prices provide a strong incentive for consumers to turn to alternative fuels wherever this is feasible. Chart III shows that the industrial countries are expected to experience the smallest percentage increase in energy consumption, the capital-surplus oil-exporting countries the largest increase. A comparison of Charts II and III provides some indication of the growing importance of non-oil fuels. The share of oil is expected to decline in all regions, while the use of other fuels, led by coal, is expected to increase.

The centrally planned economies will remain the second largest consumer of energy during the 1980s, accounting for about one-third of world energy output. As a group, these countries are projected to remain a net exporter of energy. 1/ We expect that oil production in the USSR will continue to rise, although at a much slower rate than during past decades. At the same time, the USSR will become a major exporter of natural gas. In addition, China will play an increasingly important role as a net exporter of energy. In this region, coal will remain the main fuel during the 1980s, with natural gas replacing oil in many end uses.

The developing countries currently consume only about 14 percent of world energy supplies. This share is projected to increase to about 20 percent by 1990. This comparatively steep increase in energy consumption reflects the expectation that their economies will grow considerably faster than the industrial or the centrally planned economies with a concomitant growth of cities and industrial and transportation sectors. It also reflects the rapid growth in their population. We project that during the 1980s their energy consumption will continue to rise faster than their GNP. Developing countries will continue to rely heavily on oil as a major source of energy. As a group, these countries will continue to rely on petroleum for more than half their energy consumption. Natural gas (in oil-exporting countries) and primary electricity (in oil-importing countries) are expected, however, to gain in importance, mainly at the expense of petroleum.

During the 1980s, the bulk of the industrial countries' energy imports will consist of oil. However, the projected decline in energy import

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1/ Some studies, however, suggest that the USSR will become a net importer of petroleum.

requirements, together with massive efforts to speed up the transition from oil to alternative fuels, is expected to lead to a significant change in the growth pattern of oil imports (Chart IV). Although OPEC and industrial countries will remain the major trading partners in the international oil markets, non-OPEC oil-exporting developing countries and the oil-importing developing countries are likely to play an increasingly important role in this market. 1/ At the same time, the importance of centrally planned economies as net oil exporters is expected to decline substantially during this decade.

## B. The Supply of Energy

Consumers have responded to the increase in oil prices by reducing the growth of overall consumption of energy and by trying to replace oil with other, less expensive fuels. Producers have responded in a similarly predictable way. The higher oil prices have provided a strong incentive to intensify the search for new oil deposits, to increase output from existing fields, and to step up the production of non-oil energy resources. Since the first oil price increase in 1973/74, investments in the oil industry worldwide have doubled in real terms. The coal industry has raised its output to a level that is exceeding current demand and depressing coal prices. Most countries have also made major efforts to expand the production of primary electricity from hydro, nuclear, and geothermal resources, which are projected to provide more than 40 percent of the incremental energy supplies in the 1980s.

The projected incremental production of petroleum, natural gas, solid fuels (coal), and primary electricity in the five country groups during the 1980s is shown in Chart V. 2/ Charts VI and VII focus on the changes in the

---

1/ A striking feature of the projections for the oil-importing developing countries is that, although their energy production is expected to more than treble between 1980 and 1990, their energy import requirements--largely consisting of oil--will increase by almost 50 percent to over 26 percent of the world energy trade in 1990, up from 20 percent in 1980.

2/ Incremental energy supplies appear to be consistent with the estimated rates of return on investments. Petroleum seems to offer the highest returns, followed by hydroelectricity. Comparable returns on investments in coal were obtainable only in a few selected locations.

Chart IV: WORLD NET TRADE IN PETROLEUM
BY MAJOR COUNTRY GROUP,
1960-90

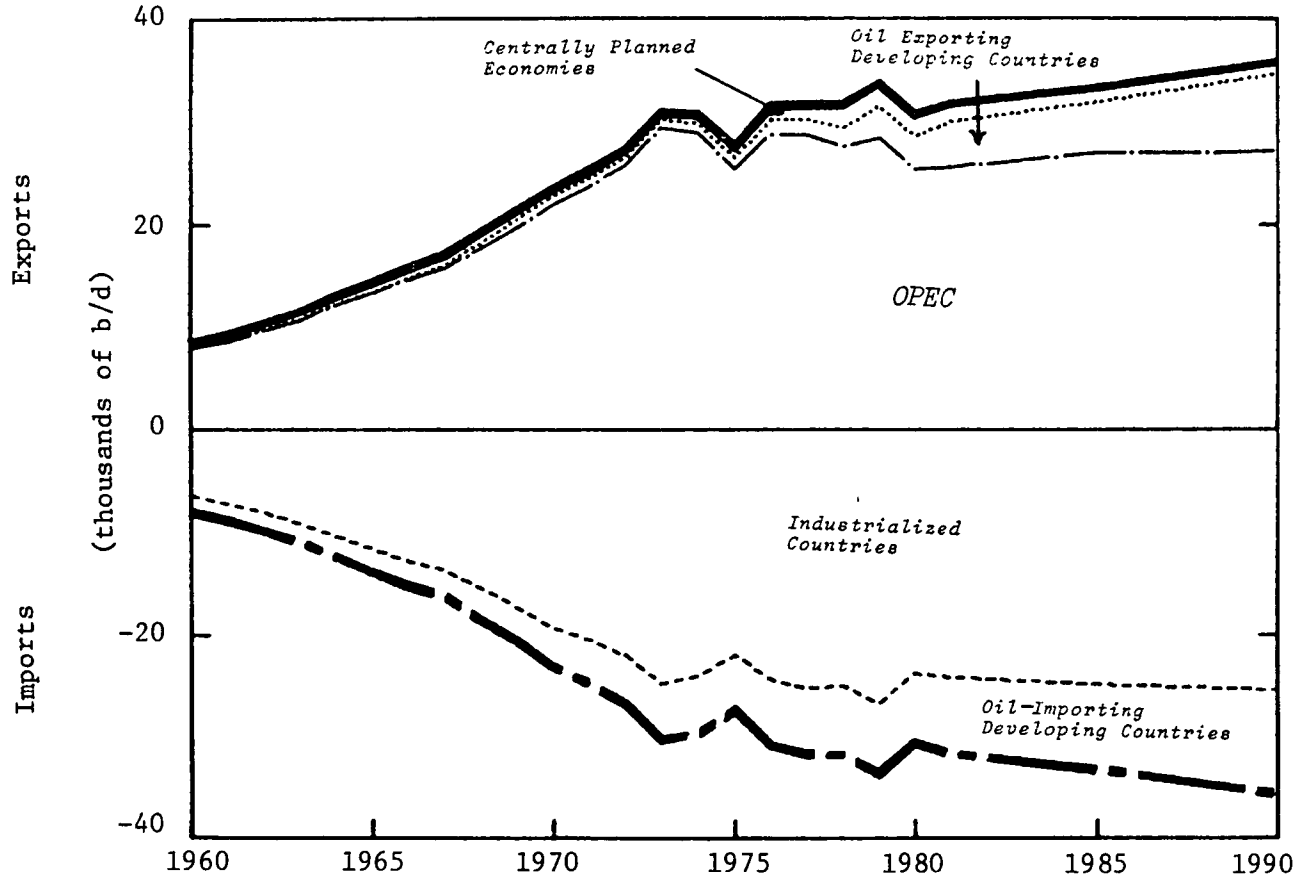


Chart V: PROJECTED INCREMENTAL WORLD ENERGY PRODUCTION BY COUNTRY GROUP, 1980-90

(Percentage Total Relative Increase)

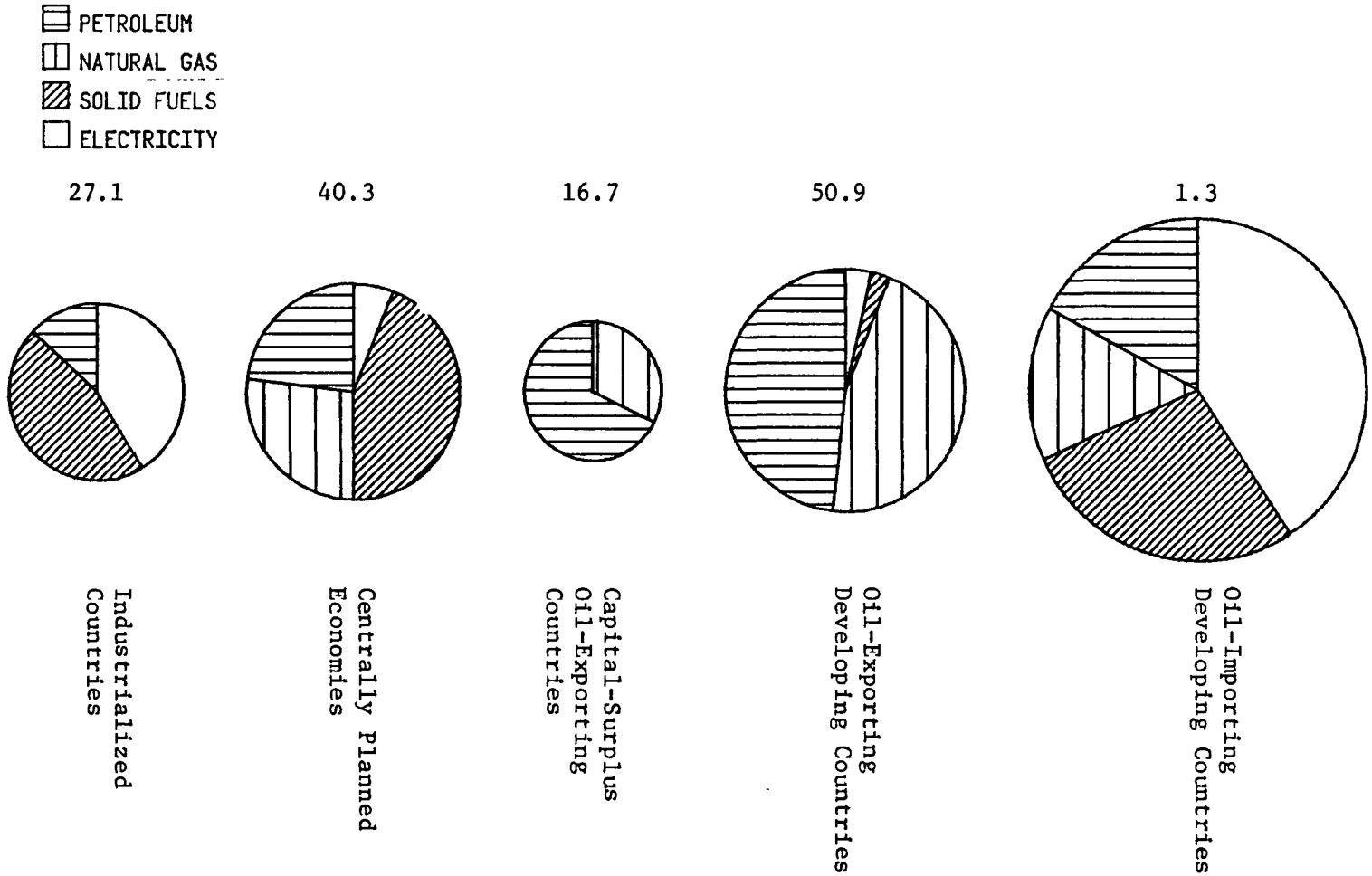


Chart VI: SHARES OF MAJOR FUELS IN WORLD PRIMARY COMMERCIAL ENERGY PRODUCTION, 1960-2000

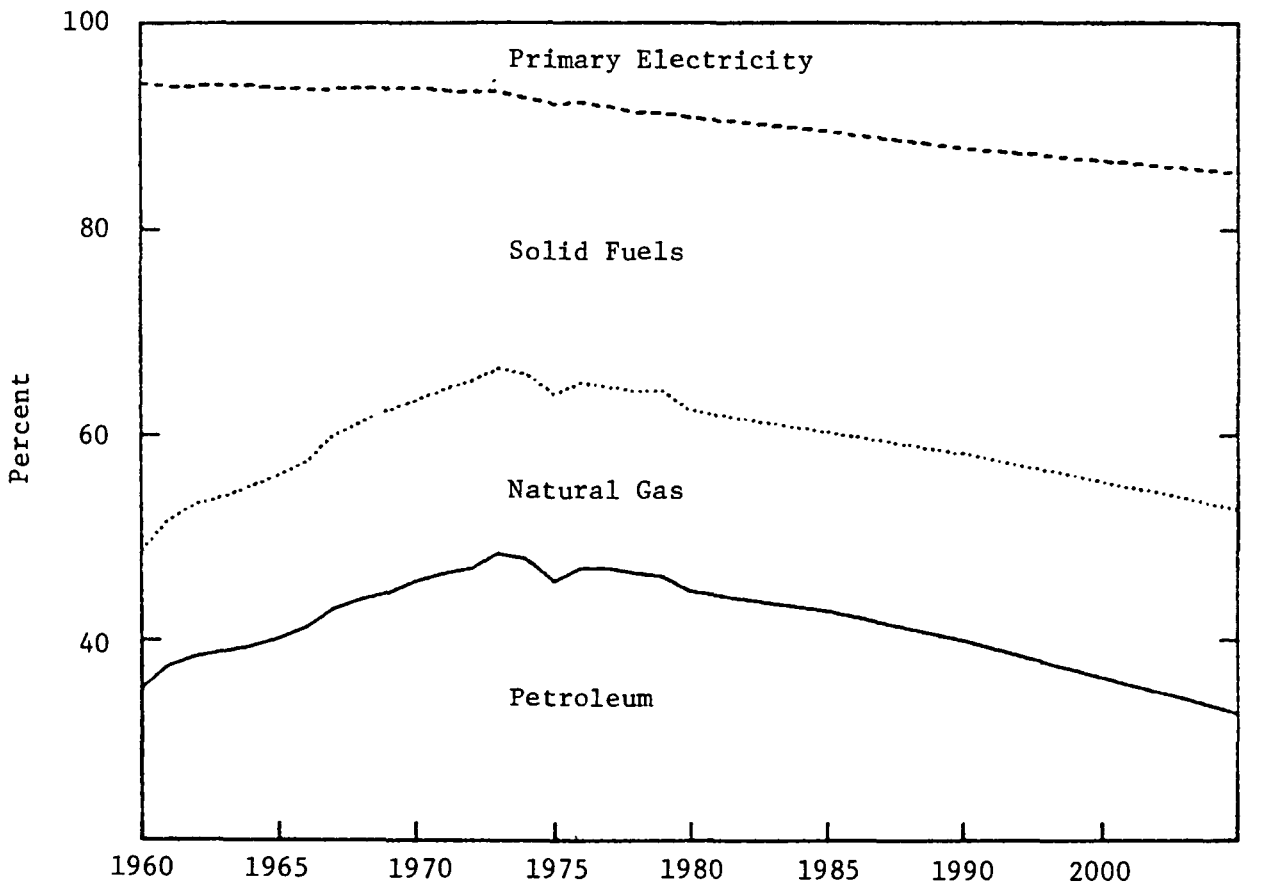
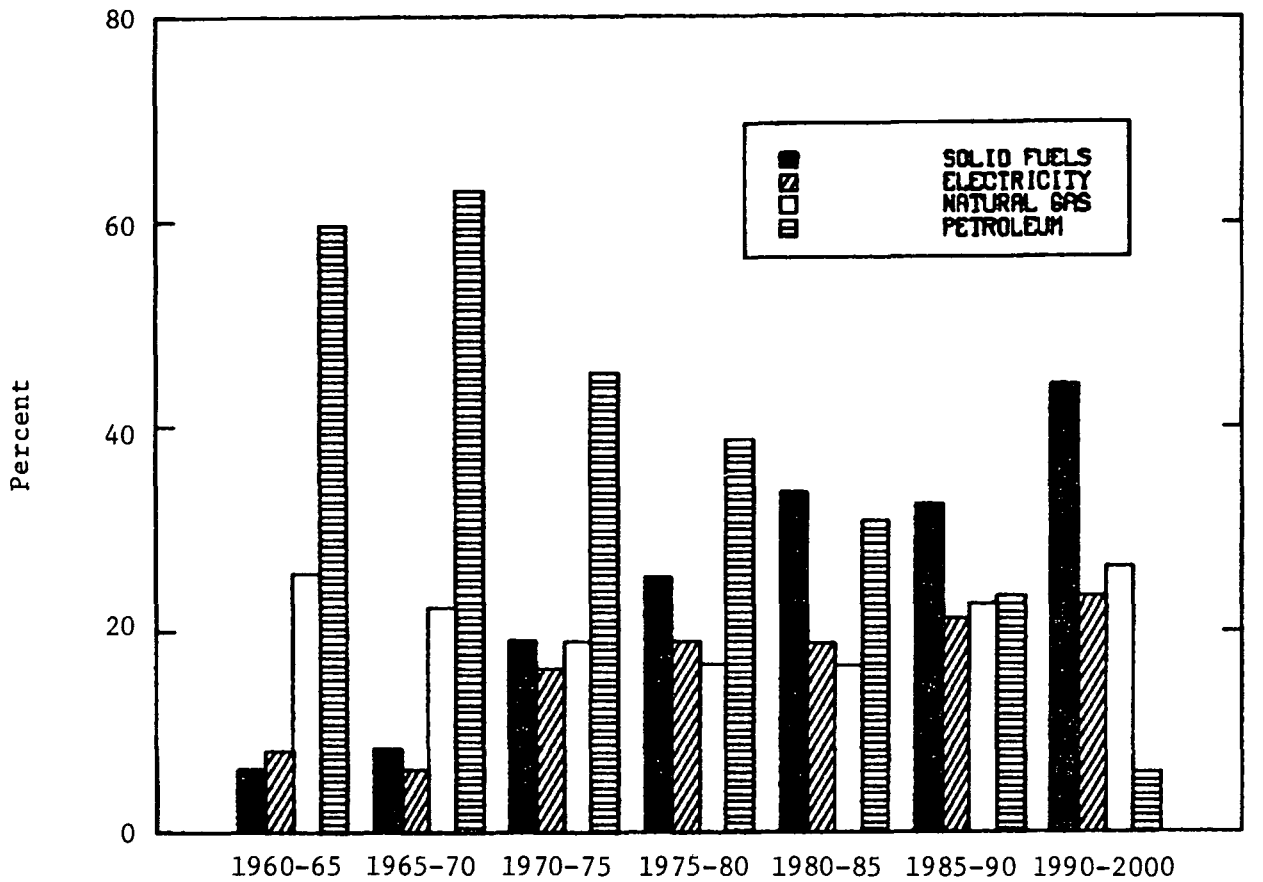


Chart VII: INCREASES IN PRIMARY COMMERCIAL ENERGY PRODUCTION BY MAJOR FUELS, 1960-2000



importance of the various fuels from a global viewpoint and over a longer time horizon.

The three charts show that oil will continue to play a major role in the energy markets and that the transition to alternative fuels will take place gradually during the next decade. Oil has dominated commercial energy supplies since the early 1950s; despite the current emphasis on the development of non-oil energy resources, it will continue to supply 40 percent of the world's commercial energy needs in 1990. The supply of conventional natural gas is projected to maintain its current share of about 20 percent of world energy supplies. However, this level will only be possible if extensive distribution systems are constructed.

The uncertainties that surround future oil supplies are reflected in the production projections for the capital-surplus oil-exporting countries. Their net exports are projected to grow only by about 2.3 million barrels per day (mbd) between 1980 and 1990. Several of these countries which have large reserves relative to their current production levels have adopted strict conservation policies and are increasing their production capacities only slowly, if at all. Kuwait and Libya, for example, announced lower ceilings for oil production. Saudi Arabia, which could increase its capacity to 12 mbd in the mid-1980s, has placed a nominal ceiling of 8.5 mbd on its production. That figure was, however, exceeded to compensate for the world supply shortfalls of 1979 and 1980. Iraq has a great potential for increasing its production substantially during the 1980s, but the duration and effects of the Iran-Iraq war make it difficult to evaluate its role as a significant supplier.

The growth of energy production (mostly oil and natural gas) in the other oil-exporting developing countries is projected to exceed the increase in their domestic consumption. Hence, their share in world energy exports will increase during the 1980s. While OPEC countries are projected to increase their output of natural gas, their production of oil is likely to remain at around 30 mbd; however, several countries not belonging to OPEC--Mexico and to a lesser extent Egypt, Malaysia, and some West African countries--are expected to increase their oil production substantially.

Since the oil price increase in 1973/74, coal, which was still the world's most important source of energy during the 1950s, 1/ is currently the frontrunner in the field of possible substitutes for petroleum. Unlike many other fuels, coal is found in large quantities in many parts of the world; the technologies of mining, moving, and use of coal are well-established; and coal can be converted into liquid and gaseous fuels that could be marketed through the existing network of pipelines, etc. Perhaps even more important, coal liquids would be compatible with the existing stock of energy-using equipment. However, coal has two major disadvantages vis-a-vis oil: its use causes more environmental pollution, and it is more difficult to handle and transport. 2/

Because of the long lead times involved in expanding coal production and transport capacities, estimated coal output in the 1980s reflects to a large extent investment decisions that have already been made. We project that about 90 percent of the world's coal output will come from mines in industrial countries and centrally planned economies, including an expansion of the highly mechanized, large-scale stripmining operations in Canada, the United States, and Australia.

During the 1980s, coal will be used primarily in traditional combustion processes to generate energy. Only a small share of the projected coal output will be converted into gas or liquid fuels. However, this share is projected to increase substantially during the 1990s.

Thermal power will continue to dominate electric power generation during the current decade. However, its share is expected to decline as the use of nuclear and hydropower resources expands, particularly in developing countries. We project that the net oil-importing countries will show the largest increase in primary electricity generation during the 1980s.

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1/ In 1950, coal accounted for 60 percent of total primary energy production, while oil provided only 30 percent. By 1973, coal's share in world energy supplies had fallen to 30 percent, whereas oil's share had increased to 50 percent.

2/ Only 8 percent of the world's coal production is traded, whereas nearly 60 percent of the oil produced is traded--mostly from the Middle East to Europe, the United States, and Japan.

Nuclear energy is likely to continue to be the most economic energy resource for electricity generation where the potential for hydroelectric power generation has been exhausted. We project that the share of nuclear energy in total energy supplies will increase at a slower rate than projected before the Three Mile Island incident--from 2 percent in 1980 to 6 percent in 1990. If there were a lessening in the current concerns about nuclear safety and environmental impact within the next few years, the use of nuclear energy could expand considerably faster than is foreseen in this paper.

Synthetic fuels have received a great deal of attention since the oil price increase in 1973/74, and considerable progress has been made in improving existing technologies and in developing new ones. Although some cost estimates of synthetic fuels are below current oil prices, we do not foresee that there will be large-scale industrial application of these technologies during the 1980s. Aggregate supplies of synthetic fuels are projected to account for less than 2 percent of world energy demand by 1990.

## C. Energy Prices

Since 1973, petroleum prices have increased twelvefold in nominal terms and almost fivefold in real terms. There appears to be consensus that the level of export petroleum prices will be determined in the longer term by the production costs of substitutes to conventional petroleum. Based on available estimates of these production costs, there could be a doubling of oil prices in real terms during the next two decades. In our projections, we have assumed that the average OPEC price for oil will reach a level of about US$45-65 (in 1980 prices) by the end of the century. Taking the midpoint of this range this would imply an average increase in oil prices of about 3 percent a year.

# II. ENERGY DEMAND PROSPECTS

## A. Adjustments in the Demand for Energy

### 1. Conservation and Increased Energy Efficiency

In the decade ahead, energy efficiency and conservation will play increasingly important roles in shaping energy demand. The available statistical evidence strongly points to this likelihood. Examples of energy savings through improved energy efficiency fostered by various conservation measures abound for almost all economic sectors. Before the sharp increase in energy prices in 1973/74, energy consumption in industrial countries grew at about the same rate as their national product. In developing countries, energy consumption grew somewhat faster than real GNP. Since energy has become more expensive, consumption has increased at a significantly slower rate, a rate that has been significantly reduced by the increases in domestic energy prices.

In most countries, the increase in the average international price for petroleum has led to drastic increases in domestic prices for petroleum and to a lesser increase in those of non-petroleum fuels. The adjustment of domestic prices to the higher international prices, however, has varied widely among countries. The availability of indigenous energy resources as well as differences in the economic and energy conditions of the various countries have shaped the adjustment of domestic prices in each country. Table 2 provides an overview of the energy price adjustments that have taken place in selected country groups. 1/

Although many interesting details about the adjustment of domestic energy prices to higher international prices are lost in summary tables such as Table 2, they do reveal the broad trends. The energy prices to final consumers have increased more steeply in oil-importing countries than in oil-

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1/ The centrally planned economies are not shown because the relevant price data have not been available.

Table 2: INDEX OF ENERGY PRICES (IN REAL TERMS) TO FINAL USERS IN SELECTED MAJOR COUNTRY GROUPS, 1975-80

(1973=100)

| Country Group | 1975 | 1978 | 1980 /a |
|---|---|---|---|
| Industrial Countries /b | 133 | 144 | 195 |
| Capital-Surplus Oil Exporters /a | 90 | 80 | 70 |
| Oil-Exporting Developing Countries /c | 125 | 125 /a | 160 |
| Oil-Importing Developing Countries /c | 141 | 150 /a | 200 |

/a Estimated.
/b Average of seven major industrial countries.
/c Average based on a sample of developing countries in each group.

Source: World Bank and the International Energy Agency (IEA).

exporting ones. 1/ Analysis of the price data in individual countries shows that, on the average, the more dependent countries have been on imports to meet their domestic energy requirements, the quicker they have adjusted their domestic prices to those prevailing in the international markets. An example is the rapid adjustment of domestic energy prices in oil-importing developing countries.

The rate of increase of non-petroleum energy prices has generally been slower than that for petroleum products. As a consequence, the price

1/ Most countries exercise some form of control over the pricing of their indigenous energy supplies. Before 1973, when international petroleum prices were low in comparison with current levels, domestic price controls provided a barrier against the inflow of "cheap foreign oil." The justification for this kind of protective barrier disappeared when OPEC sharply increased the price of its oil in 1973/74. However, price controls were initially maintained and justified on the argument that they would soften the impact of the oil price increase on final consumers. Public resistance to a removal of price controls began to weaken after the second major increase in OPEC prices in 1978. Yet, in many oil-exporting developing countries domestic prices remain well below international levels.

differential between petroleum and non-petroleum fuels has widened, and the economic incentive to replace petroleum by using more of the less expensive non-petroleum fuels has increased. Consider, for example, natural gas, which is a close substitute for petroleum in many end uses. Its price continues to lag behind the increases in petroleum prices. In part this is because of long-term supply contracts, which are common in this market, and in part because of the domestic price controls that have been in effect in major consuming countries. 1/ Coal prices have adjusted even more slowly than natural gas prices, mainly because of the transportation problems and environmental concerns that have constrained the use of coal. Electricity prices have adjusted the most slowly of the three fuels. Part of this lag can be explained by the declining use of petroleum in electricity generation, by the small share of the cost of fuel in the total production costs of electricity, and by the fact that a significant portion of total electricity output comes from hydro and nuclear power stations.

During the 1973-78 period, the share of petroleum in the total demand for energy declined slightly in oil-importing countries. However, it was primary electricity--nuclear in the industrial countries, and hydro in the oil-importing developing countries--which contributed the most in replacing the more expensive petroleum (Table 3). In oil-exporting countries, the share of petroleum did not change significantly during the period.

Rising energy prices have led to improvements in the efficiency with which energy is being used in almost all economic sectors. In the transportation sector, for example, there has been a trend toward more energy-efficient automobiles. Government regulations and the growing demand for small cars has led to a shift in U.S. automobile production toward small and medium-size models. 2/ It is estimated that the number of cars in the United

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1/ Deregulation has led to a sharp increase in natural gas prices to final consumers in the United States. However, in terms of its BTU equivalent, natural gas is still priced far below petroleum.

2/ Until recently, automobile manufacturers were able to improve energy efficiency by reducing the weight of their cars. (In 1979, the average automobile manufactured in the U.S. weighed 700 pounds less than in 1974.) In the future, further increases in energy efficiency will come from new engine and body designs, as well as from the use of even lighter materials.

Table 3: SHIFTS IN THE SHARES OF DIFFERENT FUELS IN PRIMARY ENERGY CONSUMPTION

(percent)

| Country Group | 1973 | | | | 1978 | | | |
|---|---|---|---|---|---|---|---|---|
| | Petroleum | Coal | Natural Gas | Primary Electricity | Petroleum | Coal | Natural Gas | Primary Electricity |
| Industrial Countries | 51.5 | 18.5 | 21.2 | 8.7 | 49.6 | 18.9 | 20.7 | 10.9 |
| Capital-Surplus Oil Exporters | 75.0 | - | 25.0 | - | 75.0 | - | 25.0 | - |
| Oil-Exporting Developing Countries | 66.7 | 3.0 | 24.2 | 6.1 | 66.7 | 3.9 | 21.6 | 7.8 |
| Oil-Importing Developing Countries | 57.8 | 26.5 | 3.9 | 11.8 | 56.2 | 26.2 | 3.8 | 13.8 |

\- Negligible.

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22).

States will grow from 110 million units in 1979 to 140 million units by the year 2000, but their total petroleum consumption is expected to decline by 30 percent.

As a result of the trend toward lighter cars, the demand for steel by the automobile industry has declined. A similar trend toward smaller and lighter ships in the shipbuilding industry has added to the drop in steel demand. At the same time, a growing share of the world's steel output is being produced through the more energy-efficient continuous casting process. While traditional steel-making processes require that the iron ingots be reheated before they are rolled into steel products, in continuous casting the iron-steel products are never allowed to cool.

Because of the structural changes that have taken place in the industries that use steel products and the increased energy efficiency in the production of steel itself, economic growth in the future is expected to be accompanied not only by a proportionately smaller demand for steel, but, even more important, by a significant decline in the energy content of steel products. Similar examples can be found in almost all industries.

It is difficult to pinpoint the sector which has contributed the most to energy conservation. Table 4 provides a sectoral breakdown of energy consumption in industrial countries between 1973 and 1978. (Similar data were not available for developing countries.) In the seven major industrial countries, the final prices of energy paid by industrial users increased fastest between 1973 and 1980, followed by residential users and the transportation sector. It is therefore probably true that the pressure for conservation was greatest in the industrial sector. At the same time, however, residential energy demand was also heavily curtailed. Gasoline and diesel oil consumption for road transport, however, continued to increase until 1978. Not until 1979, when gasoline prices doubled, did consumption of these fuels begin to decline.

Table 4: SECTORAL SHARES OF TOTAL FINAL ENERGY CONSUMPTION IN OECD COUNTRIES

(percent)

| Sector | 1974 | 1978 |
|---|---|---|
| Industrial Sector | 37.6 | 34.4 |
| Iron and Steel | 8.9 | 6.8 |
| Chemical | 3.4 | 3.7 |
| Petrochemical | 4.3 | 4.8 |
| Other | 21.0 | 19.3 |
| Transportation | 25.7 | 28.1 |
| Road | 20.9 | 23.4 |
| Air | 2.9 | 3.1 |
| Other | 1.9 | 1.6 |
| Other Sectors | 32.6 | 33.7 |
| Agriculture | 1.1 | 1.1 |
| Residential/Commercial | 31.2 | 31.8 |
| Public Service | 0.3 | 0.8 |
| Non-Energy Use | 4.0 | 3.8 |

Source: IEA, Energy Balances of OECD Countries, 1974-78.

The rate of adjustment toward a more efficient use of energy depends not only on the pricing mechanism, but also on the economic life of the existing stock of capital goods. On the one hand, the results of energy demand studies have clearly shown that consumers respond to higher energy prices by reducing their energy consumption, and that these reductions become more pronounced over time. On the other hand, the economic life of many capital goods prolongs the adjustment to higher energy prices, as consumers weigh the gains from using more energy-efficient capital against the investment costs in new equipment and the higher energy costs associated with the continued use of less energy-efficient capital. This is one of the reasons why energy savings in residential and commercial sectors have been small compared with those in other economic sectors. Most of the adjustments that did not require a change

in capital stock (buildings, etc.), such as more efficient control over the heating and cooling of large buildings, have been carried out. The change to more energy-efficient buildings is expected to be slow because of the high capital costs of insulating existing buildings and their long economic life (30-50 years) compared with most other capital goods.

In sum, the continued rise in energy prices--combined with public incentives, government regulations, and other conservation measures--is expected to accelerate the shift toward less energy consumption per unit of output; that is, toward a lower energy intensity of production.

## 2. Changes in Energy Intensities

Energy intensity is usually measured in terms of primary commercial energy consumption per dollar of real GDP. Up to 1973, energy intensity remained almost constant in industrial countries; in developing countries, energy intensities increased considerably. Table 5 shows the trends before and after 1973 for market-economy countries. In industrial countries, energy consumption per dollar of real GDP declined by about 12 percent between 1973 and 1980.

The decline in energy intensity was significantly larger during the second round of price increases (1979/80) than in the first (1973/74), although prices to end users in real terms increased by about the same percentage rate during both rounds. 1/ For the oil-importing developing countries, the increase in energy prices meant a halt in the earlier trend of rising energy intensities. However, the oil-exporting countries continued to use more energy per unit of output than in the past. The trend of energy use in these countries reflected the small impact that domestic energy prices have on consumption when compared with the strong effect of rising national incomes.

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1/ One likely explanation is the considerable time lag that is involved in the adjustment of energy consumption to higher prices.

Table 5: ENERGY INTENSITY INDEXES

(1973=100)

| Country Group | 1960 | 1975 | 1978 | 1980 /a |
|---|---|---|---|---|
| Industrial Countries | 100 | 96 | 93 | 88 |
| Capital-Surplus Oil-Exporting Countries | 80 | 113 | 140 | 133 |
| Oil-Exporting Developing Countries | 89 | 105 | 118 | 121 |
| Oil-Importing Developing Countries | 79 | 98 | 100 | 98 |

/a Estimated.

Source: World Bank and IEA.

## B. Energy Demand Prospects for the 1980s

### 1. Methodology and Assumptions

Energy Demand Elasticities. The demand for energy represents the demands for the various fuels (gasoline, fuel oils, natural gas, coal, electricity, etc.) by the various energy-using activities. The energy demand of each of these activities responds in a unique way to changes in the prices of the various energy resources and to changes in incomes. Ideally, therefore, energy demand should be measured (and projected) for as many activities as possible. While data for energy consumption (by sector and by major fuels) are generally available for industrial countries, they are often lacking for developing countries and centrally planned economies.

The energy demand projections in this paper rest on the following demand model:

$$\frac{\Delta E}{E} = e_p \cdot \frac{\Delta P}{P} + e_y \cdot \frac{\Delta GDP}{GDP}$$

where:

$\frac{\Delta E}{E}$ = percent change in energy demand

$\frac{\Delta P}{P}$ = percent change in average international prices for petroleum

$\frac{\Delta GDP}{GDP}$ = percent change in GDP

$e_p$ = price elasticity

$e_y$ = income elasticity.

Data for this type of demand model are generally available, and it is possible to estimate the price and income elasticities for each country. Studies by Choe 1/, Hoffmann and Mors 2/, and others 3/ have used mostly time-series data to estimate these parameters. Because of the length of the time series--most of the series that were used for this analysis reach back into the early 1950s and 1960s--the estimated coefficients largely reflect the energy situation before 1973, a time when energy supplies were plentiful and real energy prices were falling. Clearly, this situation is no longer relevant and should not be reflected in the coefficients used for the purpose of projections. At the same time, the experience since 1973 has been too short for a meaningful econometric analysis.

Thus, to arrive at elasticities that could be used for projecting energy demand, two approaches have been pursued. One consists of using a cross-sectional analysis; that is, using the demand and price data of several countries for one specific year, since those data usually contain a greater variation in prices than the time-series data of individual countries. The second approach uses technical information on the potential for energy conservation at various price levels. Table 6 provides an overview of the typical range of elasticities that were obtained from these studies.

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1/ Choe, B.J., "Energy Demand Prospects in Non-OPEC Developing Countries," in Workshops on Energy Supply and Demand, International Energy Agency, Paris, 1978, pp. 422-440.

2/ Hoffmann, L., and M. Mors, "Energy Demand in the Developing World: Estimation and Projection up to 1990 by Region and Country," Regensburg University, mimeograph, October 1979.

3/ Energy Modeling Forum, "Aggregate Elasticity of Energy Demand," Volume 1, Stanford University, Stanford, Calif., August 1980.

Table 6: LONG-RUN ENERGY DEMAND ELASTICITIES

| Country Group | Income Elasticity | | Price Elasticity | |
|---|---|---|---|---|
| Industrial Countries | 0.8 | 1.1 | -0.1 | -0.7 /a |
| Developing Countries | 1.2 | 1.9 | -0.2 | -0.6 |

/a With respect to the energy price at the wholesale level before taxes.

Source: The Energy Modeling Forum and the World Bank.

The Energy Modeling Forum (Stanford University) has compared the elasticity estimates of several energy demand studies for the industrial countries. It found that long-run price elasticities range from -0.1 to -0.7. Most of the estimates obtained using time-series data belonged to the lower end of this range, while the cross-sectional data, or a combination of cross-sectional and time-series data, yielded elasticity estimates that approached the upper end of the range. The energy demand projections for the developing countries were based on elasticity estimates by Choe, Hoffmann, and Mors. Their studies show that the long-run income elasticities of developing countries are significantly larger than one. 1/ The average income elasticity was estimated at 1.3, and the corresponding average long-term price elasticity at -0.3.

Dynamic Energy Demand Adjustments. The model and the parameters described above that were used for the energy demand projections in this paper do not take into account the sometimes complicated and lengthy adjustment process energy users go through when prices or income levels change. There is still little empirical evidence on the dynamic aspects of energy demand adjustments. Energy is always consumed jointly with the services of some capital good. Hence, the demand for energy can be varied by adjusting the

1/ Hoffmann and Mors found that structural changes in developing countries, such as the increasing share of industrial output, for example, are responsible for the greater-than-unitary income elasticity.

utilization rate of these capital goods, by modifying the efficiency with which these capital goods consume energy, or, finally, by replacing the existing capital stock with a more energy-efficient one. The path along which energy consumption adjusts over a longer time horizon depends, in theory, on the extent to which each of these three types of adjustment interact at each point in time.

Up to now, studies of dynamic energy demand behavior have not been able to identify this adjustment path. Most researchers have simply assumed a certain shape for the adjustment path and then have observed how well it fit the available data. Griffin, 1/ for example, used a polynomial lag distribution that yields an adjustment path that approaches a certain target value at the end of the period. He used this type of approach to estimate the adjustment of energy use in the industrial and residential/commercial sectors, but his results were highly inconclusive. These and similar studies convinced us that more research is needed before dynamic demand adjustment models can be used with confidence to project global energy demand.

## 2. Energy Demand Projections for Major Country Groups

Industrial Countries. The industrial countries dominate world energy markets. They produce more than one-third of the world's energy output and slightly less than one-quarter of the world's petroleum output. At the same time, they consume slightly more than half the world's energy production.

Before the increase in energy prices in 1973, energy consumption in the industrial countries increased at about the same rate as their aggregate economic growth. The rise in energy prices slowed the growth in energy consumption--partly because of energy conservation measures and partly because of improved efficiency in the utilization of energy--thereby weakening the close link to economic growth. Between 1960 and 1973, energy consumption in the industrial countries had grown at an average annual rate of 5.1 percent. During this period, the economies of industrial countries grew at about the same rate. Between 1973 and 1978, however, the growth rate of energy consumption declined to 0.3 percent, that of economic growth to 2.5 percent.

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1/ Griffin, J., Energy Conservation in the OECD: 1980 to 2000, Ballinger Publishing Company, Cambridge, Mass., 1979.

This pattern of adjustment to higher energy prices is likely to continue well into the 1990s. During the decade of the 1980s, energy consumption in the industrial countries is projected to regain some of the momentum that was lost in the years immediately following the sudden jump in oil prices. We project that energy consumption will grow at an average rate of almost 1.9 percent during the 1980s (Table 7). The corresponding economic growth projection is about 3.2 percent.

As Table 7 shows, petroleum is projected to account for more than 40 percent of total energy consumption by 1990, and it is unlikely that this share will decline substantially during the next decade. During the 1980s, the growing energy demand of industrial countries will be met mainly by expanding primary electricity production and the use of coal.

Centrally Planned Economies. We project that the centrally planned economies will remain net exporters of energy during the 1980s. However, the composition of their exports is likely to shift in favor of more natural gas and less petroleum. The following discussion of the energy situation in the two largest consuming countries, the USSR and China, 1/ will shed some more light on this change in the composition of the centrally planned economies' energy exports.

Energy Demand in the USSR: In the past, the USSR produced enough energy for its own domestic needs and those of its Eastern European allies and was still able to export increasing quantities of oil and natural gas to Western Europe. However, reports about likely developments in the energy sector in the USSR are conflicting. Experts seem to agree that the USSR has the largest reserves of hydrocarbons, but since most of these reserves are in Siberia, the USSR faces difficult problems in recovery and transport. There is little doubt that petroleum production at existing fields in the western part of the USSR will decline during the 1980s. At the same time, however, natural gas production will more than compensate for this shortfall in petroleum. Natural gas met about 6 percent of the USSR's energy needs in 1960 and 14 percent in 1980 and is projected to supply almost 20 percent by 1990.

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1/ The USSR and China together account for 75 percent of the energy consumption of centrally planned economies and 81 percent of their total energy production.

Table 7: ENERGY CONSUMPTION IN INDUSTRIAL COUNTRIES, 1960-90

| Energy Source | 1960 | | 1970 | | 1973 | | 1978 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) |
| Petroleum | 14.2 | 39.6 | 29.9 | 49.3 | 35.5 | 51.5 | 34.7 | 49.6 | 35.0 | 48.4 | 37.4 | 43.0 |
| Natural Gas | 6.7 | 18.7 | 12.8 | 21.1 | 14.6 | 21.2 | 14.5 | 20.7 | 15.0 | 20.7 | 16.2 | 18.6 |
| Solid Fuels | 12.3 | 34.2 | 13.3 | 22.0 | 12.8 | 18.6 | 13.2 | 18.8 | 14.0 | 19.3 | 19.1 | 22.0 |
| Primary Electricity | 2.7 | 7.5 | 4.6 | 7.6 | 6.0 | 8.7 | 7.6 | 10.9 | 8.4 | 11.6 | 14.3 | 16.4 |
| TOTAL | 35.9 | 100.0 | 60.6 | 100.0 | 68.9 | 100.0 | 70.0 | 100.0 | 72.4 | 100.0 | 87.0 | 100.0 |

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22); World Bank projections.

Hence, the bulk of the energy exports of the USSR in the later part of the 1980s will be in the form of natural gas.

Primary electricity has always played a minor role in the USSR, meeting less than 1 percent of its energy needs. Only 12 percent of its total electricity output comes from hydro resources, less than 2 percent from nuclear power. Most of the electricity comes from plants that are powered by fossil fuels. 1/

Industry is not only the largest energy-consuming sector in the USSR, it is also the largest consumer of electricity. Although the share of energy-intensive industries in total industrial production is likely to decline during the next two decades, the demand for electric power is projected to increase. The growing demand for electricity will come mainly from the need to increase productivity and to obtain higher recovery ratios in the processing of metals and minerals.

The domestic sector is the second largest energy consumer in the USSR. New housing developments are now mostly serviced by district heating. The severe winters and relatively higher fuel costs in the European regions of the USSR were the main reasons for the widespread use of central heat from thermal power plants.

Overall energy efficiency is unlikely to increase in the USSR during the 1980s. According to Soviet reports, there seems to be little possibility of further increasing the efficiency of power and steam generation. At the same time, these two energy sectors are projected to grow more rapidly than any other sector. In transportation, further gains in energy efficiency in freight transport are unlikely. Overall energy use in this sector will be determined largely by the government's policy concerning the expansion of the automobile industry. In the agricultural sector, there is a distinct trend toward more energy-intensive production. With increasing mechanization in the domestic and commercial sectors, efficiency gains from district heating are unlikely to check per capita consumption growth.

In sum, there are no indications that the USSR will experience a similar "delinking" between its domestic energy consumption and its economic growth as has occurred in the industrial countries of the West.

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1/ Electricity could play a major role in the transfer of energy from Siberia to the industrial centers in the western parts of the USSR.

Energy Demand in China: Energy consumption in China grew from 6 mbd oil equivalent in 1960 to 11.2 mbd in 1979. This corresponds to an average growth rate of 3.4 percent a year. The share of coal, which supplied more than 95 percent of China's energy needs, declined steadily during the past two decades as the shares of other fuels, led by petroleum and primary electricity, expanded. However, at present more than three-fourths of China's energy needs are still met by coal.

China has been a net exporter of energy since the middle of the 1960s. In 1973, it began to export growing quantities of petroleum. Currently, the figure is around 250,000 barrels per day (b/d).

Somewhat less than two-thirds of China's domestic energy needs originate in its industrial sector. 1/ Agriculture, which claims only 6 percent of total demand, has been by far the most rapidly growing energy consumer. The residential and commercial sectors together account for slightly less than one-third of total energy demand. The present share of the transportation sector is only about 5 percent.

In an effort to modernize its industrial plants, in recent years China has increasingly been replacing its old coal-burning equipment with newer machinery that uses petroleum. The resulting increase in efficiency has been obtained with a minimum of new investment. Domestic petroleum consumption is also likely to increase when China's plans to expand its petrochemical industry materialize.

Until the 1960s, the Eastern European members of the CMEA 2/ were, as a group, small net exporters of energy; they were exporting coal and oil to Western European countries. When these energy surpluses ended in the early 1960s, the growing requirements of oil and gas in these countries were met by the USSR, which in 1978 supplied 80 percent of the total imports of these countries.

The increase in oil prices, together with other factors, has led to a rapid growth in foreign debt in some of these countries. The energy demand

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1/ This sector also includes the generation of electric power.

2/ The following countries belong to the Council for Mutual Economic Assistance (CMEA): Bulgaria, Czechoslovakia, Democratic Republic of Germany, Hungary, Poland, Romania, and the USSR.

situation in these countries closely resembles that of the whole group of centrally planned economies: heavy reliance on coal as the major source of energy is likely to continue during the 1980s, but demand for petroleum and natural gas is projected to expand rapidly (Table 8).

Developing Countries. Developing countries (including the capital-surplus oil-exporting countries) currently produce about 30 percent of world energy supplies. At the same time, they consume less than 15 percent of these supplies. 1/

Although the developing countries' share in world energy consumption is currently small, it is expected to expand more rapidly than in the rest of the world. There are several reasons for this expectation. First, developing countries will have to maintain higher economic growth rates than the rest of the world to avoid a decline in the living standards of their rapidly growing populations. Second, more rapid economic growth will be accompanied by growing industrial production and urbanization, which will boost the demand for energy. Third, as income levels increase, demand for various energy-consuming amenities (automobiles, electric appliances, etc.) could rise dramatically from their present low levels. Finally, substitution of commercial for non-commerical energy 2/ is likely to continue. Thus, during the 1980s, energy demand in developing countries will grow almost three times as fast as in industrial countries (Table 9).

As Table 9 shows, petroleum accounts for nearly 60 percent of the commercial energy consumption of developing countries. This share is slightly higher in the net oil-exporting countries (Tables 10 and 11). During the 1980s this share is expected to decline in both groups of countries. The share will continue to be smaller in the oil-importing developing countries,

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1/ Our energy projections for developing countries indicate that both shares will change only slightly during the 1980s: developing countries will increase their share in world supplies to about one-third, in world consumption to less than 20 percent.

2/ Commercial energy refers in this context to the four major fuels: petroleum, natural gas, coal, and primary electricity. The share of commercial energy consumption in the total amount of energy consumed varies widely among developing countries. Studies carried out by the World Bank and other organizations indicate that it ranges from about 15 percent in newly industrialized countries to almost 60 percent in low-income developing countries.

Table 8: ENERGY CONSUMPTION IN CENTRALLY PLANNED ECONOMIES, 1960-90

| Energy Source | 1960 | | 1970 | | 1973 | | 1978 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) |
| Petroleum | 3.0 | 16.0 | 7.2 | 26.1 | 9.3 | 28.7 | 12.6 | 30.3 | 13.1 | 30.5 | 17.3 | 27.9 |
| Natural Gas | 1.1 | 5.8 | 3.8 | 13.8 | 4.8 | 14.8 | 7.0 | 16.8 | 7.0 | 16.3 | 12.3 | 19.8 |
| Solid Fuels | 14.3 | 76.1 | 15.7 | 56.9 | 17.3 | 53.4 | 20.3 | 48.8 | 20.9 | 48.6 | 29.4 | 47.3 |
| Primary Electricity | 0.4 | 2.1 | 0.9 | 3.2 | 1.0 | 3.1 | 1.7 | 4.1 | 2.0 | 4.6 | 3.1 | 5.0 |
| TOTAL | 18.8 | 100.0 | 27.6 | 100.0 | 32.4 | 100.0 | 41.6 | 10.0 | 43.0 | 100.0 | 62.1 | 100.0 |

Source: UN, World Energy Supplies 1973-78 (Series J, No.22); World Bank projections.

Table 9: ENERGY CONSUMPTION IN DEVELOPING COUNTRIES, 1960-90

| Energy Source | 1960 | | 1970 | | 1973 | | 1978 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) |
| Petroleum | 2.6 | 50.0 | 6.2 | 56.9 | 8.5 | 61.1 | 11.5 | 60.9 | 11.6 | 57.8 | 17.8 | 49.5 |
| Natural Gas | 0.3 | 5.8 | 1.1 | 10.1 | 1.3 | 9.4 | 1.8 | 9.5 | 2.3 | 11.4 | 5.7 | 15.8 |
| Solid Fuels | 1.9 | 36.5 | 2.5 | 22.9 | 2.7 | 19.4 | 3.4 | 18.0 | 3.8 | 18.9 | 6.7 | 18.6 |
| Primary Electricity | 0.4 | 7.7 | 1.1 | 10.1 | 1.4 | 10.1 | 2.2 | 11.6 | 2.4 | 11.9 | 5.8 | 16.1 |
| TOTAL | 5.2 | 100.0 | 10.9 | 100.0 | 13.9 | 100.0 | 18.9 | 100.0 | 20.1 | 100.0 | 36.0 | 100.0 |

Source: UN, World Energy Supplies 1973-79 (Series J, No. 22); World Bank projections.

Table 10: ENERGY CONSUMPTION IN NET OIL-EXPORTING DEVELOPING COUNTRIES, 1960-90

| Energy Source | 1960 | | 1970 | | 1973 | | 1978 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) |
| Petroleum | 0.9 | 69.2 | 1.8 | 64.3 | 2.2 | 66.7 | 3.5 | 68.6 | 3.6 | 65.5 | 5.5 | 55.0 |
| Natural Gas | 0.2 | 15.4 | 0.7 | 25.0 | 0.8 | 24.2 | 1.1 | 21.6 | 1.4 | 25.4 | 3.5 | 35.0 |
| Solid Fuels | 0.1 | 7.7 | 0.1 | 3.6 | 0.1 | 3.0 | 0.1 | 2.0 | 0.1 | 1.8 | 0.3 | 3.0 |
| Primary Electricity | 0.1 | 7.7 | 0.2 | 7.1 | 0.2 | 6.1 | 0.4 | 7.8 | 0.4 | 7.3 | 0.7 | 7.0 |
| TOTAL | 1.3 | 100.0 | 2.8 | 100.0 | 3.3 | 100.0 | 5.1 | 100.0 | 5.5 | 100.0 | 10.0 | 100.0 |

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22); World Bank projections.

Table 11: ENERGY CONSUMPTION IN NET OIL-IMPORTING DEVELOPING COUNTRIES, 1960-90

| Energy Source | 1960 | | 1970 | | 1973 | | 1978 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) | (mbd) | (%) |
| Petroleum | 1.6 | 42.1 | 4.2 | 53.9 | 6.0 | 58.8 | 7.4 | 56.9 | 7.3 | 53.3 | 11.2 | 46.1 |
| Natural Gas | 0.1 | 2.6 | 0.3 | 3.8 | 0.4 | 3.9 | 0.5 | 3.9 | 0.7 | 5.1 | 1.6 | 6.6 |
| Solid Fuels | 1.8 | 47.4 | 2.4 | 30.8 | 2.6 | 25.5 | 3.3 | 25.4 | 3.7 | 27.0 | 6.4 | 26.3 |
| Primary Electricity | 0.3 | 7.9 | 0.9 | 11.5 | 1.2 | 11.8 | 1.8 | 13.8 | 2.0 | 14.6 | 5.1 | 21.0 |
| TOTAL | 3.8 | 100.0 | 7.8 | 100.0 | 10.2 | 100.0 | 13.0 | 100.0 | 13.7 | 100.0 | 24.3 | 100.0 |

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22); World Bank projections.

mainly because of differences in the energy pricing policies of these two groups of countries. As was mentioned earlier, the oil-importing developing countries have adjusted their domestic energy prices to world market levels, while many of the oil-exporting developing countries continue to sell petroleum and natural gas below international market prices.

The scope for energy conservation in developing countries is considerably smaller than in industrial countries or in some centrally planned economies. While improvements in the energy efficiency of industrial production will undoubtedly take place as developing countries import increasingly more energy-efficient equipment and machinery from industrial countries, the potential for energy conservation is particularly limited in the non-industrial sectors of most developing countries. With the exception of the transportation and the industrial sectors, most of the other sectors (agriculture, commercial, residential, etc.) rely heavily on traditional fuels. Although the efficiency with which these traditional fuels (firewood, dung, etc.) are used could be improved in many cases (e.g., through more efficient wood-burning stoves), most attempts to do so have had only marginal success up to now. Any shift from traditional to commercial fuels would place additional strain on the import bill of oil-importing developing countries. 1/

We project that developing countries will continue to rely heavily on oil in their domestic consumption of energy throughout the 1980s. Although both groups of countries--the net oil-exporting as well as the net oil-importing--will expand their use of natural gas, in the latter group of countries the pressure to replace petroleum will be answered by increased use of primary electricity (Table 9).

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1/ It is estimated that the demand for oil in developing countries will rise by 15-20 percent if all households that now use traditional fuels switch to kerosene.

# III. ENERGY SUPPLY PROSPECTS

## A. World Crude Petroleum and Natural Gas Supplies

The world's capacity to produce crude oil and natural gas is constrained by the size of existing reserves, the rate at which new reserves are found and developed, and the geological characteristics of reservoirs. It also depends on the production or conservation policies of oil-exporting countries. These two sets of issues are discussed below.

### 1. Changes in Investment and Reserve Levels

For some years now, world reserves of oil have been declining relative to production (Table 12). The bulk of the world's reserves, principally in the Middle East, was built up in most part during the 1960s. Despite the increased incentives to explore for oil provided by higher prices, conventional oil production is projected to reach a plateau around the turn of the century.

There is little doubt that finding and developing the world's as yet undiscovered oil reserves will be progressively more difficult and costly. Many are in remote locations or harsh operating environments, such as the Arctic, which will be technologically demanding and will require long lead times for development. Fields remaining to be discovered in areas where production has already taken place are expected to be, on the average, smaller than past discoveries. On the other hand, most of the developing countries that depend heavily on oil imports have not yet been fully explored. At the same time, while these countries may have many small fields, it is reasonably certain that they will not be as easily exploitable as those found in the Middle East.

Table 12: PETROLEUM RESERVES AND PRODUCTION, 1960-80

| | Reserves /a | | | Production | | | Ratio of Reserves to Production /b | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1970 | 1980 | 1960 | 1970 | 1980 | 1960 | 1970 | 1980 |
| | (billion barrels) | | | | | | | | |
| OPEC | 218.0 | 412.4 | 434.3 | 3.2 | 8.6 | 9.8 | 68.1 | 48.0 | 44.3 |
| Non-OPEC | 83.0 | 199.0 | 214.2 | 4.8 | 8.6 | 12.9 | 17.3 | 23.1 | 16.6 |
| World | 301.0 | 611.4 | 648.5 | 8.0 | 17.2 | 22.7 | 37.6 | 35.5 | 28.6 |

/a At year end.
/b This provides an indication of the number of years reserves would last at respective production levels.

Source: World Oil, various issues.

The current level of reserves reflects the changes in oil and gas consumption and the investment pattern of the oil industry during the past two decades. Before 1973, the bulk of investments was aimed at the development of the large and more profitable oil fields in OPEC countries. Investments in crude oil and natural gas facilities grew, worldwide, by 20 percent during the 1960s and early 1970s. 1/ Since 1973, higher oil prices have led to higher investments 2/ in non-OPEC areas.

Published information and data on investments in the petroleum and natural gas industries are sparse and highly fragmentary. However, available data indicate clearly that investment patterns have changed considerably since the early 1970s. For example, in the United States, investments in oil production jumped by 30 percent (in real terms) after the oil price increases in

1/ Chase Manhattan Bank, Capital Investments of the World Petroleum Industry, various issues.

2/ Price controls on domestic crude and natural gas in the United States, Canada, and Australia have kept investments in these countries below the levels that would have been attained without controls.

1979 and 1980. 1/ In 1980 U.S. dollars, investments in petroleum exploration and production rose from $22 billion in the early 1970s to about $52 billion a year during the latter part of the 1970s.

There was not only a change in the geographic pattern of investments--from the oil-exporting countries to the oil-importing countries— but also within the various production and distribution stages of the industry itself. Before 1973, downstream investments were tied to the expansion of oil consumption. More than half the global investments of the petroleum industry were in the areas of refining, shipping, and marketing. The slowdown in petroleum consumption resulted in markedly lower returns on downstream investments. At the same time, returns on investments in production and exploration recovered sharply from their low levels in the 1960s and 1970s. In 1978, therefore, the share of downstream investments had declined worldwide to 42 percent, from 53 percent in 1976, while the share of investments in production and exploration rose from 47 percent to 58 percent in the same period.

Table 13 shows the drilling effort in the world by major groups. While industrialized as well as oil-importing developing countries have increased their drilling efforts, developing countries seem to have placed a greater emphasis on the development of known fields than on exploration. Some evidence of this is provided by the number of "seismic party months"--an indicator of the exploratory efforts that take place before actual drilling begins--in both groups of countries (Table 14). In industrial countries, the number of exploratory wells increased by almost 50 percent, seismic party months by 46 percent during the 1970s; in oil-importing developing countries, exploratory drilling increased by 15 percent while seismic efforts declined by 8 percent. 2/ This imbalance between exploration and development efforts in oil-importing developing countries raises concern about the prospects for oil production in coming years. In the long run, increases in petroleum production depend on the availability of reserves. They, in turn, depend on the

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1/ A major force behind this large increase in investments was also the decision by the United States to gradually decontrol domestic crude oil and natural gas markets.

2/ Compared with their average level in 1970-72, seismic party months in oil-importing developing countries were 20 percent lower in 1978, but they were 64 percent higher in industrialized countries.

Table 13: WORLD DRILLING EFFORT

(thousands of feet per year)

| Country Group | 1965 | 1970/72 (Average) | 1976/78 (Average) | Percentage Change 1970/72 - 1965 | Percentage Change 1976/78 - 1970/72 |
|---|---|---|---|---|---|
| Industrial Countries | 201,169 | 153,728 | 254,608 | -23.5 | 65.6 |
| OPEC | 10,610 | 13,177 | 13,878 | 24.2 | 5.3 |
| Non-OPEC Oil Exporters | 4,660 | 6,285 | 6,350 | 34.9 | 1.0 |
| Oil-Importing Developing | 6,928 | 7,390 | 9,904 | 6.7 | 34.0 |
| WORLD | 223,367 | 180,580 | 280,740 | -19.2 | 55.5 |

Note: Includes exploratory, development, and service drilling; excludes the centrally planned economies.

Source: World Oil, various issues.

extent of exploration efforts, the ratio of productive to non-productive wells, and the productive capacity of the discoveries; that is, the number of barrels of oil or million cubic feet of gas a productive exploratory well yields.

It is too early to judge whether the slack of exploratory efforts in oil-importing developing countries is only a short-term phenomenon or some imbedded structural problem. In their response to an increase in oil or gas prices, producers commonly make, at first, every effort to raise output. 1/ Only in the longer term do they also increase their exploration efforts.

1/ Hence, the "inventory" of small gas or oil fields that had been accumulated before the price increase becomes depleted when prices rise. New exploratory efforts are necessary to replenish the "inventory."

Table 14: WORLD SEISMIC DRILLING EFFORT

(party months)

| Country Group | 1970/72 | 1976/78 | Percentage Change |
|---|---|---|---|
| Industrial Countries | 3,224 | 4,700 | 46 |
| OPEC | 850 | 826 | -3 |
| Non-OPEC Oil Exporters | 624 | 514 | -18 |
| Oil-Importing Developing | 1,135 | 1,040 | -8 |
| WORLD | 5,833 | 7,080 | 21 |

Note: Excludes the centrally planned economies.

Source: Petrocanada.

The question is why this response has been weaker in oil-importing developing countries. It has been argued that their lack of capital and skilled manpower, as well as their domestic policies with respect to oil and gas exploration, have slowed the expected response. However, the incentive to invest in oil exploration in these countries remains strong, and most have not yet been fully explored. Only about 14 percent of their estimated ultimately recoverable oil reserves have been proven.

An additional incentive for exploration in these countries is the comparatively lower cost of oil production. It is estimated that most of their prospective capacity would cost between $3,000 and $10,000 per barrel of daily capacity. Thus, investments in exploration and development projects could return, at current and projected prices for OPEC oil, between 40 to 50 percent, in some instances even as much as 100 percent. 1/

## 2. OPEC Production Policies

Oil production in the future will also depend heavily on the production policies of OPEC countries. Their policies have been shaped in recent years largely to conserve the increasingly valuable petroleum

1/ World Bank, "Energy in Developing Countries," August 1980.

resources while keeping in mind the avoidance of major dislocation in the world economy. OPEC countries view their petroleum resources as "national capital" for use in economic development. Hence, OPEC's depletion policy has to be seen in the context of its development strategy.

The challenge OPEC countries face is to achieve self-sustaining economic growth without sole dependence on oil revenues. The reliance on oil revenues will continue in the foreseeable future. Through conservation policies, OPEC countries are now attempting to strike a balance between current and future capital needs for economic development. On the one hand, a higher rate of economic development could lead to a higher rate of petroleum production. On the other hand, with worldwide inflation eroding their investments abroad, many countries will have a strong incentive to maintain a conservationist attitude. While Saudi Arabia did increase its production to offset part of the decline in Iranian exports, it cannot be expected to continue to act as a producer of last resort. OPEC countries are thus likely to adjust their petroleum output to meet their investment needs as well as to continue to avoid major dislocation of the world economy at large.

The need for revenues from oil exports is becoming an increasingly important factor in determining the oil output of OPEC countries. However, not all OPEC countries face the same need for revenues. In this respect, OPEC countries could be grouped into three categories. In the first would be countries such as Saudi Arabia, Kuwait, the United Arab Emirates (UAE), Libya, and Qatar, whose revenues are likely to be far in excess of their financial requirements. Next would be countries such as Venezuela, Iran, and Iraq, whose production at their preferred levels would generate sufficient revenue to meet their needs for sustained economic growth. In the last category would be the countries which produce close to their sustainable production, but whose revenues are insufficient to meet their capital requirements (Indonesia, Nigeria, Algeria, Bahrain, and Oman).

This classification, however, does not completely correspond with the attitude of all OPEC members on the subjects of pricing and production. Although some members advocate the need for production control and thus favor a tight market, others do not believe it is either politically expedient or in the best long-term economic interests of OPEC to follow such a policy. Countries in the third group defined above have generally had a moderating influence in the market in recent years and have repeatedly shown their willingness to increase production, within limits, to alleviate shortages.

Decisions about production and exploration in OPEC countries may sometimes be affected by political factors. It is generally agreed that the use of more efficient recovery techniques provides the cheapest and quickest way to increase supplies. While exploration is more expensive and time-consuming, it has the advantage of increasing reserves, which in turn would support a higher rate of output.

At present, the Middle East accounts for only 1 percent of all exploration efforts. Large oil companies have shifted the bulk of their exploration efforts to non-OPEC oil-producing countries. Such fields require considerable capital investments, but they are not likely to provide a substantial contribution to total petroleum resources. Equivalent exploration efforts in OPEC countries would probably lead to the discovery of significantly larger reserves.

In discussing potential oil production in the OPEC countries, it is necessary to distinguish between maximum output capacity for short periods, sustainable production capacity, and desired production. Sustainable production capacity is largely determined by the geological characteristics of the oil field, reservoir conditions, and a technically sound depletion policy. It is, therefore, always below maximum output capacity, which can only be maintained for short intervals of time. Production at a higher rate will reduce ultimate recovery.

Table 15 shows the oil production capacities for OPEC countries with the exception of Iraq and Iran (the best estimate for these two countries is a production capacity of probably now around 6.5 mbd on a sustainable basis). Some OPEC members--especially the capital-surplus countries--have announced a desired level of oil production well below sustainable production capacity. With the exception of Saudi Arabia, almost all OPEC countries that had announced a production ceiling were producing close to that ceiling in the months just prior to the outbreak of the Iraq-Iran hostilities.

## 3. Projections of Petroleum and Natural Gas Supplies

Petroleum and natural gas supplies 1/ were projected on the basis of available information about production plans, investment plans, reserves, and exploration activities in individual countries. Except for the OPEC countries, most of the projections were taken from country energy sector studies. Table 16 summarizes the petroleum projections for the major country groupings.

In the United States, crude oil and natural gas liquids (NGL) production is expected to decline from 10 mbd in 1980 to 7 mbd in 1990. Canadian crude oil and NGL production is expected to decline from 1.75 mbd in 1980 to less than 1.5 mbd in 1990. In Canada, production will depend to a large extent on the tax and energy policy decisions made by the Canadian government. Preliminary assessments indicate that production levels might fall well below those included in the aggregate projections.

Production in centrally planned economies is projected to grow at an average rate of less than 3 percent a year, and this group of countries will continue to provide about 20 percent of world oil supplies. The USSR, the world's largest producer of crude oil, accounts for about three-fourths of total oil production by centrally planned economies. Net oil exports from the centrally planned economies to the rest of the world are expected to decline from about 1.25 mbd in 1979 to about 500,000 b/d by 1990.

Production in developing countries is projected to more than double during the 1980s. A number of developing countries (Barbados, Brazil, Chile, Colombia, Ghana, Guatemala, India, Ivory Coast, Morocco, Pakistan, Philippines, Thailand, Turkey, and Yugoslavia) are expected to become either self-sufficient within the current decade, or at least to be able to reduce their dependence on imports significantly.

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1/ The same approach was also used for the supply projections of coal and primary electricity. The coal projections were provided by the Bank's Industrial Projects Department.

Table 15: MAXIMUM OUTPUT AND SUSTAINABLE PRODUCTION CAPACITIES OF THE OPEC COUNTRIES

(mbd)

| Country | Maximum Output Capacity | Sustainable Production Capacity |
|---|---|---|
| Saudi Arabia /a | 11.3 | 10.8 |
| Kuwait /a | 2.8 | 2.5 |
| UAE | 2.5 | 2.0 |
| Qatar | 0.65 | 0.5 |
| Venezuela | 2.4 | 2.2 |
| Nigeria | 2.4 | 2.2 |
| Libya | 2.1 | 1.9 |
| Indonesia | 1.6 | 1.6 |
| Algeria | 1.2 | 1.0 |
| Gabon | 0.25 | 0.25 |
| Ecuador | 0.25 | 0.25 |
| TOTAL | 27.45 | 25.2 |

/a Half of the Neutral Zone is included in Saudi Arabia, the other half in Kuwait.

Source: World Bank.

Table 16: PETROLEUM PRODUCTION BY COUNTRY GROUP, 1970-90

(mbd)

| Country Group | 1970 | 1980 | 1990 |
|---|---|---|---|
| Industrial Countries | 12.7 | 14.5 | 16.4 |
| Centrally Planned Economies | 8.0 | 13.7 | 17.9 |
| Capital-Surplus Oil-Exporting Countries | 12.7 | 18.3 | 20.4 |
| Net Oil-Exporting Developing Countries | 12.7 | 14.2 | 18.3 |
| Net Oil-Importing Developing Countries | 1.2 | 1.5 | 2.8 |
| WORLD | 47.3 | 62.2 | 75.8 |

Sources: UN, World Energy Supplies 1973-78 (Series J, No. 22); and World Bank projections.

World natural gas reserves 1/ are presently estimated at about 2,600 trillion cubic feet (Table 17). This corresponds to about 72 percent of the proven oil reserves and 15 percent of the proven coal reserves. More than 75 percent of the gas reserves are located in North America, the Middle East, and centrally planned economies.

During the past ten years, additions to gas reserves have kept pace with additions to oil reserves and are estimated at about 190 billion barrels. However, only about half the additional gas reserves are being consumed. According to some estimates, the world's ultimate recoverable gas reserves are at least equal to those of oil (1,900 billion barrels), or roughly four times the currently proven gas reserves.

1/ Until recently, gas discoveries outside the United States, Western Europe, and the USSR have not been fully evaluated, and reserve estimates should be treated with caution.

Table 17: NATURAL GAS RESERVES BY COUNTRY GROUP, 1970-80

(trillion cubic feet)

| Country Group | 1970 | 1980 |
|---|---|---|
| Industrial Countries | 491.63 | 465.22 |
| Centrally Planned Economies | 440.0 | 953.9 |
| Capital-Surplus Oil-Exporting Countries | 162.25 | 277.63 |
| Net Oil-Exporting Developing Countries | 445.25 | 856.22 |
| Net Oil-Importing Developing Countries | 49.26 | 85.53 |
| WORLD | 1,588.39 | 2,638.50 |

Note: Year end.

Source: "Worldwide Issues," The Oil and Gas Journal, Vol. 78, No. 52, December 1978.

As oil production rises, so does the production of associated gas. In the 1980s, the bulk of associated gas will come from countries that currently produce oil. Because of the expected decline in U.S. oil production and the anticipated slow expansion of North Sea production--which is expected to reach its peak between 1985 and 1990--production of associated gas 1/ is expected to remain at 5.5 to 5.6 million barrels per day of oil equivalent (mbdoe) throughout the 1980s.

At present, only a small portion of total or gross output of associated natural gas is actually used either within the producing country or for exports. Most is still flared. Reasons for the limited use of natural gas in developing countries are the limited size of the market, the high cost of transportation, and the high processing costs if gas is exported in liquid form. Gas produced in industrial countries is fully utilized.

1/ This projection refers to net or "usable" gas production.

There is a consensus that natural gas will become the largest export fuel of the USSR. The USSR is estimated to have the world's largest gas reserves. Although an increasing share of gas will have to come from the more remote areas of Western Siberia, recent reports on the construction of gas pipelines in the USSR 1/ indicate that by 1990 production in the USSR could be twice its 1978 level. Table 18 summarizes natural gas production in the major country groups.

Table 18: NATURAL GAS PRODUCTION BY COUNTRY GROUP, 1970-90

| Country Group | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|
| | (mbdoe) /a | (%) | (mbdoe) | (%) | (mbdoe) | (%) |
| Industrial Countries | 13.0 | 72.6 | 13.8 | 56.8 | 13.2 | 38.2 |
| Centrally Planned Economies | 3.8 | 21.2 | 7.7 | 31.7 | 12.6 | 36.4 |
| Capital-Surplus Oil-Exporting Countries | 0.1 | 0.6 | 0.3 | 1.2 | 1.3 | 3.8 |
| Net Oil-Exporting Developing Countries | 0.7 | 3.9 | 2.0 | 8.2 | 5.9 | 17.0 |
| Net Oil-Importing Developing Countries | 0.3 | 1.7 | 0.5 | 2.1 | 1.6 | 4.6 |
| WORLD | 17.9 | 100.0 | 24.3 | 100.0 | 34.6 | 100.0 |

/a Million barrels per day of oil equivalent.

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22), 1970; and World Bank projections.

1/ Blitzer, C., et al., "Global Energy Prospects to 1990," background report to the World Development Report, 1979, World Bank (internal circulation only).

## B. World Coal Supply

In the 1950s, coal was the world's most important source of energy--it accounted for about 60 percent of all primary energy production--whereas oil at that time met only 30 percent of world energy requirements. In recent years, the roles of the two fuels have been reversed. By 1980, the share of coal had dropped to below 30 percent, while the combined share of oil and natural gas had risen to almost 70 percent. Oil and gas have accounted for 80 percent of the increase in energy supplies since the 1950s.

The main reason for the shift away from coal to petroleum and natural gas has been the low cost of these fuels. 1/ However, the sharp increases in oil prices during the 1970s have led to renewed interest in thermal coal.

Since 1974, a substantial amount of coal exploration and pre-investment work has been undertaken in almost all developing countries, and coal mines are currently being developed in sixteen of them. These will provide an estimated annual production of 25 million tce (120 mbdoe) in the second half of the 1980s. Another twenty-eight developing countries have known coal deposits, but produce no coal at present. 2/ The bulk of the incremental production of coal in developing countries to 1990 is, as shown in Table 20, expected to come from the established coal industries in India and South Africa.

Although global as well as regional coal reserves (Table 19) could support much higher production levels for the 1980s than those shown in Table 20, potential supplies are constrained, at least in the short run, by the long lead times involved in opening new mines. Depending on the nature of the deposit, one to two years are usually required for exploration and pre-investment work. After that, it takes between two to four years to open and develop a mine. Another factor that is slowing coal supplies is the lead times and

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1/ Among the other factors that led to the shift were the ease with which they could be transported over long distances in pipelines, the fact that they caused less environmental pollution compared with coal, and the steep increase in automobile and air traffic after World War II.

2/ Coal exploration and pre-investment work have taken place in only ten of these countries. In the remaining eighteen countries, little systematic effort has been made to identify coal deposits.

Table 19: RECOVERABLE COAL RESERVES BY COUNTRY GROUP

(billion tce)

| Country Group | 1974 | 1978 |
|---|---|---|
| Industrial Countries | 321.83 | 297.001 |
| Centrally Planned Economies | 279.99 | 246.304 |
| Capital-Surplus Oil-Exporting Countries | - | - |
| Net Oil-Exporting Developing Countries | 49.856 | 3.671 |
| Net Oil-Importing Developing Countries | | 89.388 |
| WORLD | 651.676 | 636.364 |

Source: World Energy Conference, World Energy Reserves 1985-2020; National Coal Association, World Coal Trade, 1973 and 1974 issues.

Table 20: COAL PRODUCTION BY COUNTRY GROUP, 1970-90

| Country Group | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|
| | (mbdoe) | (%) | (mbdoe) | (%) | (mbdoe) | (%) |
| Industrial Countries | 13.0 | 41.3 | 13.9 | 35.4 | 20.4 | 36.4 |
| Centrally Planned Economies | 16.1 | 51.1 | 21.8 | 55.4 | 29.8 | 53.1 |
| Capital-Surplus Oil-Exporting Countries | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Net Oil-Exporting Developing Countries | 0.1 | 0.3 | 0.1 | 0.3 | 0.3 | 0.5 |
| Net Oil-Importing Developing Countries | 2.3 | 7.3 | 3.5 | 8.9 | 5.6 | 10.0 |
| WORLD | 31.5 | 100.0 | 39.3 | 100.0 | 56.1 | 100.0 |

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22), 1970; and World Bank Projections.

resources involved in constructing the transportation infrastructure—railroads, ports, and ships—that links the coal mines to consumers. Hence, considering the long lead times for coal production and transportation, the levels of coal production projected up until the latter part of the 1980s reflect to a large extent investment decisions that have already been made. 1/

Available estimates for developing countries indicate that the investment costs of coal projects (coal mines plus the associated infrastructure) exceed those of comparable oil fields. For coal projects, the costs range from US$7,000 to $15,000 for the equivalent of a barrel of oil per day; the comparable costs for oil projects fall between US$3,000 to $7,000. Returns 2/ from oil projects continue to exceed those from most coal projects, despite the recent price increases in international coal prices.

During the 1980s, 90 percent of the world's coal output will continue to be mined in industrial countries and centrally planned economies (Table 20). In particular, there will be an expansion of the highly mechanized, large-scale stripmining operations in Canada, the United States, and Australia. The mining costs of these operations are low ($6 to $10 per ton) compared with underground mining operations ($20 to $30 per ton). 3/

The USSR, Poland, East Germany, and China will continue to produce the bulk of the coal output in centrally planned economies. However, there will be some significant changes in the USSR and China. In the former, coal production will shift increasingly to Siberia. Output from the European mines has declined steadily during recent years, mainly because many are depleted,

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1/ Since the lead times are somewhat longer in most developing countries compared with industrialized countries, this statement has a greater bearing on coal projections for developing countries. However, a drastic change in the anticipated investment programs for coal during the next few years could significantly affect the supply projections for the late 1980s.

2/ Although returns from oil projects in developing countries average about 40 percent, coal projects only yield between 10 to 15 percent. Returns increase to 20 to 40 percent in projects that involve the expansion of existing mines.

3/ Some of the subsidized underground mines in the European Economic Community (EEC) report production costs that range from $45 to $95 per ton. Note that the lowest underground mining costs are attained in South Africa, where low labor costs and favorable geological conditions bring the costs of a ton of coal down to less than $10.

but also because they face labor shortages and transportation problems. It is expected that any increase in the coal mining operations in Siberia will have to deal with difficult and expensive transport to get the coal to theindustrial centers in the western part of the USSR. Even the generation of thermal power at locations in Siberia would involve transmission problems over long distances, problems which have not yet been resolved.

Among the centrally planned economies, China appears to have the best prospects for a rapid expansion of coal production. At present, one-third of China's coal output comes from more than 20,000 small rural mines and pits. Available output and employment data indicate that only one-third of all coal mining operations are mechanized. 1/ In 1978, China embarked on a modernization and mechanization program for its coal industry with foreign participation.

Considering the enormous size of the recoverable resources of coal and the strong economic incentives to expand coal production, there seems to be no resource constraint on the production of coal in the foreseeable future, and certainly not in the decade ahead. However, constraints on the use of coal--ranging from environmental, health, and safety issues to economic and technical considerations--are slowing the growth of the industry. Some of these issues--such as land damage from open pit and underground mining, acid drainage from coal mine refuse, emission of noxious gases, safe disposal of ashes, and the controversial effects of carbon dioxide on the climate--have

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1/ This accounts for the low labor productivity of Chinese coal production. In Kailuan, China's most advanced coal-producing region, the average daily output is about 2 tons of raw coal per manshift underground. In Shanshi, China's leading coal mine province, the output is less than 1 ton per man per day. These output levels compare with around 15 tons per man per day in the mines of Australia and the United States and 1.8 to 3.8 tons in Western Europe.

become major public concerns in recent years. 1/ Some of the technical constraints are to a large extent the result of decades of ample supplies of relatively inexpensive liquid and gaseous fuels. The current transportation network as well as most of the energy-using equipment were designed with these fuels in mind. Available estimates indicate that the capital costs associated with adapting these transportation and end-use systems to coal would be about ten times as much as the capital cost required to produce an additional ton of coal. 2/ In addition to transportation problems, the use of coal faces serious environmental restrictions because of its high ash and sulphur content. These environmental concerns are significantly greater in industrial countries than in most developing countries.

During the 1980s, most of the energy generated from coal will come from combustion. Only a small share (about 3 percent) will be converted into gas or liquid fuels. However, this share is likely to increase substantially during the 1990s. 3/ In industrial countries, electricity generation will continue to absorb about two-thirds of coal supplies. Less stringent environmental restrictions in developing countries are likely to result in a more rapid expansion of coal use than in industrial countries, again mainly for electricity generation.

With the diminishing prospects for nuclear energy and increasing uncertainties about the prospects for petroleum, there is a growing realization that coal may well have to carry a large burden in satisfying the increased needs for energy until renewable forms of energy become available in sufficient quantities. Projections for coal production and consumption made

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1/ Technological advances have, however, reduced some of the negative effects associated with the increased use of coal. Underground coal gasification and fluidized bed combustion, for example, have considerably lowered the level of noxious emissions. There has also been considerable progress in mixing pulverized coal with oil for use as a boiler fuel, thus partially reducing the investment involved in the conversion of oil-burning to coal-burning boilers.

2/ Investments per ton of additional production capacity were estimated at $53 in 1978 dollars at the mine and at about $500 at the users' end.

3/ Coal in the form of gas or liquid has an advantage in that it can utilize the existing pipeline and transportation network, as well as the energy-using capital stock.

by EXXON, OECD, and the WOCOL 1/ study are shown in Table 21. Both EXXON's and OECD's estimates are higher than the "moderate case" of the WOCOL study. The "moderate case" is based on the existing economic, technological, and political environments in OECD countries and assumes that coal consumption will grow at the same rate as during the 1973-79 period.

## C. World Primary Electricity Supply

Although thermal power will continue to dominate power generation during the 1980s, its share will decline, since nuclear and hydropower are expected to expand their shares. Table 22 shows that the share of primary electricity generation 2/ is projected to decline in all major country groups with the exception of the net oil-importing developing countries.

### 1. Hydropower

Approximately half the world's hydropower potential is located in developing countries. Up to now, only an estimated 10 percent of this potential has been developed. Although most developing countries have been gradually expanding their hydropower capacity, its competitiveness has increased considerably since the oil price increase in 1973. 3/ Most developing countries have now completed hydro surveys and feasibility studies for exploiting their hydro potential, and the recent large oil price increases have made previously uneconomical sites attractive. However, because of the long lead time for such projects, hydro capacity is expected to expand only slowly during this decade.

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1/ Carroll L. Wilson, Coal--Bridge to the Future. Report of the World Coal Study (Cambridge, Ballinger Publishing Company, 1980).

2/ Primary energy production refers to the generation of electricity from hydropower, nuclear power, and geothermal resources.

3/ Where natural gas is available in large quantities, gas-fired power plants become economically competitive with hydroelectric plants. Natural gas gains an additional competitive edge over hydropower if flaring or venting of the gas is the only alternative to its use in power generation.

Table 21: COMPARISON OF WORLD COAL SUPPLY PROJECTIONS

(mbdoe)

| Country Group | 1977 | EXXON 1985 | EXXON 1990 | WOCOL /a Moderate 1985 | WOCOL /a Moderate 1990 | WOCOL /a High 1985 | WOCOL /a High 1990 | WOCOL /a OECD 1985 | WOCOL /a OECD 1990 | WDR IV /b 1985 | WDR IV /b 1990 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OECD /c | 15.1 | 18.3 | 21.5 | 16.2 | 19.7 | 18.0 | 25.2 | 17.7 | 22.5 | 16.7 | 20.3 |
| Developing Countries | 2.1 | 3.5 | 5.0 | 3.4 | 4.8 | 4.4 | 6.9 | 3.0 | 4.2 | 4.9 | 5.9 |
| WORLD /d | 17.3 | 21.8 | 26.5 | 19.6 | 24.5 | 22.4 | 32.1 | 20.7 | 26.7 | 21.6 | 26.2 |

/a World Coal Study, MIT.
/b World Development Report, 1981 (New York, Oxford University Press, 1981).
/c Refers to "industrial countries" in the case of WDR IV projections.
/d Excludes centrally planned economies.

Source: Economic Analysis and Projections Department, Commodities and Export Projections Division (World Bank).

Table 22: PRODUCTION OF PRIMARY ELECTRICITY BY COUNTRY GROUP, 1970-90

| Country Group | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|
| | (mbdoe) | (%) | (mbdoe) | (%) | (mbdoe) | (%) |
| Industrial Countries | 4.5 | 69.3 | 8.4 | 65.7 | 14.3 | 61.6 |
| Centrally Planned Economies | 0.9 | 13.8 | 2.0 | 15.6 | 3.1 | 13.4 |
| Capital-Surplus Oil-Exporting Countries | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Net Oil-Exporting Developing Countries | 0.2 | 3.1 | 0.4 | 3.1 | 0.7 | 3.0 |
| Net Oil-Importing Developing Countries | 0.9 | 13.8 | 2.0 | 15.6 | 5.1 | 22.0 |
| WORLD | 6.5 | 100.0 | 12.8 | 100.0 | 23.2 | 100.0 |

Source: UN, World Energy Supplies 1973-78 (Series J, No. 22); and World Bank projections.

## 2. Geothermal Power

Geothermal energy harnesses the internal heat of the earth in the form of hot water or steam to generate electricity. In several countries (e.g., Iceland, Italy, New Zealand, and the United States), geothermal energy is currently used for space heating, hot water supply, and electric power generation. Geothermal resources are geographically widely distributed and represent a competitive source of low-cost power in many developing countries.

Countries that have a substantial geothermal potential include El Salvador, Indonesia, Kenya, Mexico, Nicaragua, the Philippines, and Turkey. However, only a small portion of the geothermal potential in developing countries has so far been developed, mainly because alternative sources of energy have been cheaper and partly because geothermal energy must be used for heating or converted to electric power close to the place where it is found.

Total production of energy from geothermal sources is projected to account for less than 1 percent of the total electricity generation of oil-importing developing countries by 1990.

3. Nuclear Power

In 1980, 10 percent of the world's electricity was supplied by nuclear power stations located mainly in Europe, Japan, North America, and the USSR. In developing countries, less than 2 percent of electricity was generated by nuclear power plants. 1/ The combined capacity of these plants totals about 3.4 gigawatts (GW).

During the early 1970s, it was generally believed that nuclear power would alleviate most of the supply pressures caused by the growing scarcity of oil. Project Independence was launched in the United States, for example, calling for nuclear power to supply 30 to 40 percent of America's electricity by the end of the 1980s. Since the middle of the 1970s, however, public confidence in the safety and economics of nuclear energy has been dwindling in many countries. The debate about safety initially focused on the disposal of radioactive waste, but took on new dimensions after the reactor accident at Three Mile Island, Pennsylvania. In 1979, total cancelled capacity reached 20 GW, and large cancellations followed in 1980. However, the decline in orders stemmed not only from the growing concern about nuclear safety, but in part from the much slower than anticipated growth in electrical energy demand in the industrial countries following the oil price increases. Currently, the only countries with large nuclear programs are France, 2/ Japan, and the USSR. A recent estimate indicates that plants on order or under construction will raise nuclear capacity in the world (excluding the centrally planned economies) from 225 GW at present to some 310 GW by 1990.

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1/ Argentina, Brazil, India, Korea, and Pakistan are among the developing countries that plan to increase their nuclear capacity; Mexico, the Philippines, Romania, and Yugoslavia have nuclear units under construction; by 1990, Egypt, Portugal, Thailand, and Turkey may have nuclear units in service.

2/ France is currently reviewing its nuclear power program.

## D. Synthetic Fuels

The term "synthetic fuels" covers a wide range of energy resources. However, there are basically only four sources from which "synthetic fuels"--in gaseous or liquid form--are currently being recovered: coal; heavy oils including tar sands; oil shales; and animal or vegetable wastes.

Synthetic fuels have received a great deal of attention since 1974, and substantial progress has been made in improving existing technologies and developing new technologies for the extraction of oil and gas from these three resources. At present, however, the large-scale industrial application of these technologies is small compared with the production of conventional fuels (petroleum, natural gas, coal, and primary electricity).

Up to now, economic considerations have prohibited the extensive development of these resources. In Table 23, the production costs of conventional fuels are compared to those of various synthetic fuels. Given the oil prices at the beginning of 1979, none of the synthetic fuels could have been recovered economically. 1/ Increasing oil prices and the expectation that these prices are not likely to drop again in real terms (over the long run) have now created the necessary economic conditions for the development of synthetic fuel industries.

### 1. Heavy Oil

Global reserves of heavy oil are estimated to be five times larger and more widely spread than conventional oil resources. However, production of heavy oils faces two major obstacles. First, extraction of the heavy oils from reservoir rocks is often difficult and expensive. Second, heavy oils are too viscous to be pumped through pipelines over long distances and thus have to be refined near the production site.

Canada is currently the major producer of heavy oil. Its total production amounts to about 200,000 b/d, and the plan is to raise output to

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1/ The first plant, which was installed on the Athabasca Tar Sand region and which produced nearly 60,000 b/d, did not yield its first profit until oil prices in Canada were allowed to increase.

500,000 b/d by the late 1980s. Projects in several developing countries (mainly Venezuela) are expected to raise global production of heavy oils to almost 1 mbd by the end of the 1980s.

## 2. Oil Shale

Oil shale is a finely textured rock that contains a solid organic material called kerogen. When the oil shale is heated, the kerogen yields a crude oil that is similar to conventional crude oil. It can be further refined into the familiar petroleum products. The costs of synthetic oil from shale are estimated to be about $18.3 per barrel for a plant producing 46,200 b/d of a sulphur-free, low nitrogen, medium gravity product. More than 75 percent of the product is in the diesel fuel or jet fuel boiling range.

Although shale oil is recovered commercially in China and the USSR, further expansion of commercial operations depends to a large extent on improvements in recovery techniques. On the one hand, above-ground retorting at present requires substantial amounts of fresh water (about 5 gallons of water per gallon of kerogen); on the other hand, underground combustion is hard to control.

Shale oil is also burned directly for power generation. This application is not ruled out in other shale-oil-rich areas, but, because of the low calorific value of shale compared with bituminous coal and fuel oil, large furnaces are required. Waste disposal problems are similar to those faced in above-ground retorting.

Oil shale is projected to contribute about 500,000 b/d by 1990 to global oil supplies. About 400,000 b/d will come from existing projects in the United States.

## 3. Coal Gasification and Liquefaction

The conversion of coal into gas or liquid fuels poses an attractive alternative to the conventional use of coal in combustion processes. Gas and oil could be transported through the existing pipeline network, and their use would avoid many environmental problems. Further, the technologies for coal

Table 23: PRODUCTION COSTS OF VARIOUS FUEL TECHNOLOGIES

(1980 US$ per barrel of oil equivalent)

| Production Cost | Fuel Technologies (ranked by production cost) |
|---|---|
| 0 - 30 | - Coal<br>- U.S. crude petroleum<br>- Natural gas<br>- Tar sands<br>- Oil shale<br>- Oil sands |
| 31 - 55 | - Liquefied natural gas<br>- Light Arabian crude<br>- Wood to methanol<br>- Wood to ethanol<br>- Coal liquefaction<br>- Coal gasification, advanced gasifier, high-BTU gas<br>- Coal gasification, commercially proven medium-BTU gas<br>- Direct coal liquefaction to gasoline |
| 56 - 85 | - Coal gasification, commercially proven high-BTU gas<br>- Coal to methanol<br>- Mobil M gasoline |
| 85 and above | - Wood to high-BTU gas<br>- Manure to high-BTU gas<br>- Fischer-Tropsch to gasoline and distillate fuels<br>- Corn to ethanol |

Note: Costs include all investment requirements and operation and maintenance costs, including rate of return. Estimates are based on state-of-the-art scales of operation and U.S. operating conditions.

gasification and liquefaction do exist. 1/ However, the current market prospects for oil and natural gas and the comparatively high production costs of coal liquids will probably limit the production of synthetic fuels from coal to medium-BTU gas during the 1980s. Coal liquefaction and the production of high-BTU gas, a close substitute for natural gas that could be marketed through existing pipelines, are projected to become commercially viable during the latter part of the next decade.

Coal-processing technologies are highly sensitive to the costs of coal, which accounts for about 50 percent of the operating cost of a gas-processing facility. The coal conversion attained in pilot plant tests has ranged from 76 to 94 percent; still, the average cost of the high-BTU gas is over 20 percent higher than the delivered price of imported liquid natural gas. Medium-BTU gas, which has a heating value of 250 to 500 BTU per standard cubic foot, can be produced at a lower cost ($3.50 per million BTU) and is particularly attractive for industrial uses. 2/

Production of gas and oil from all the plants expected to be operational by 1990 is projected to amount to 200,000 b/d of oil equivalent. 3/ Considering that the lead times for commercial plants are six to ten years, any plant that could be in operation in 1990 would have to be already under construction or in the advanced planning stage.

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1/ During World War II, Germany produced up to 18,000 b/d of synthetic fuels from coal using an earlier version of the Fischer-Tropsch technology. This technology is currently used in the SASOL plant in South Africa. The third segment of SASOL is now under construction. The entire facility will eventually produce about 100,000 b/d. The SASOL plant, however, will no longer be cost-effective as soon as the cost of coal begins to exceed its current low price in South Africa.

2/ Gas-using industries have to downgrade pipeline natural gas (to about 1,000 BTU per standard cubic foot) to control combustion. This process involves a cost that is not incurred when medium-BTU gas is burned. In addition, the supply prospects for medium-BTU gas appear to be good at the current and projected prices for natural gas and coal.

3/ This is a considerable downward revision from the goals of the Synthetic Fuels Corporation of the United States: 330,000 b/d in 1987 and 1.3 mbd in 1992.

## IV. PRICE IMPLICATIONS

Petroleum prices have increased almost fivefold in real terms since 1973. There appears to be a consensus that energy prices will continue to rise in real terms over the longer run to the level of the costs of substitutes for conventional petroleum. Given the estimates of the production costs of substitutes, this means that current petroleum prices would have to double in real terms during the next two decades. If this happened, petroleum prices would rise from an average OPEC price of US$30.5 per barrel in 1980 to a level of US$45-65 (in 1980 prices) by the end of the century.

Petroleum from conventional sources is projected to meet about 40 percent of the total energy requirements of the 1980s. OPEC countries are likely to supply 50 percent of the world's petroleum needs, but their aggregate production is unlikely to exceed 32 mbd in 1990. This is a key factor underlying the energy balance projections for the 1980s.

Most of the increase in OPEC countries' producing capacity occurred during the 1960s. While it would appear that current and prospective market conditions will provide enough incentive for investments in capacity expansion in OPEC countries, OPEC's maximum sustainable production capacity has not changed significantly since the early 1970s. Investments in expanding existing production capacity have been small, and since 1973 the bulk of production has come from fields developed by former concessions.

The slow expansion of production capacity in capital-surplus OPEC countries during the 1970s has been attributed to the low return on their investments of excess revenues in foreign assets. In developing OPEC countries, additions to petroleum-producing capacity have been constrained by the priority given to investments in other sectors and a certain unwillingness to finance expansion of the petroleum sector with external borrowing.

The perceived inadequacy of the availability of OPEC petroleum to meet the world's export demands in the next two decades has led to the view that petroleum prices will increase in real terms until they reach the production costs of substitute fuels. There is less consensus, however, on the likely shape of the price trajectory. The price pattern since 1973/74 has been characterized by sharp price increases followed by a limited erosion of prices in real terms. This pattern might continue during the next two

decades, but it is assumed here that average OPEC petroleum prices during the 1980s will fluctuate around a trend growth rate of about 3 percent a year in real terms.

There is no doubt that consuming countries would prefer a gradual increase in petroleum prices to the violent price fluctuations of the past. A gradual real increase in the price of petroleum on the order of 2 to 4 percent a year is unlikely to have a major negative impact on inflation and growth in the industrial countries. Considering that the share of energy in total production cost is less than 10 percent, a rise in energy prices may add not more than half a percentage point to inflation, even if allowance is made for cumulative effects. Furthermore, a gradual increase would signal investment requirements as early as possible. 1/ However, achieving such a smooth trajectory would require more control over price changes by OPEC than appears to be feasible at the moment. The introduction of multi-tier pricing in 1979 is frequently taken as an indication that OPEC can no longer control petroleum prices unilaterally and might be a sign that the actions of independent buyers and sellers will dictate the level of petroleum prices in the short term.

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1/ However, it is unrealistic to expect a significant supply reaction to higher prices in the 1980s beyond the level of supplies projected in this report. The adjustment burden during this period will have to be carried by demand. At the same time, the increase in supplies triggered by price increases during the 1980s will ease the adjustment problem of the 1990s.

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PUB HG3881.5.W57 W67 no.489
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