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Report No. 3076

Energy in the Developing Countries

To Bd 8/5/80

July 1980

Office of the Vice President, Operations

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Document of the World Bank

CONVERSION FACTORS

APPROXIMATE CONVERSION FACTORS FOR CRUDE OIL*

INTO / FROM	Metric Tons	Barrels	Kilolitres (cub. metres)	1,000 Gallons (U.S.)
	MULTIPLY BY			
Metric Tons	1	7.33	1.16	0.308
Barrels	0.136	1	0.159	0.042
Kilolitres (cub. metres)	0.863	6.29	1	0.264
1,000 Gallons (Imp.)	3.91	28.6	4.55	1.201
1,000 Gallons (U.S.)	3.25	23.8	3.79	1

TO CONVERT	FROM			
	Barrels to Metric Tons	Metric Tons to Barrels	1,000 Barrels/Day to Tons/Year	Tons/Year to Barrels/Day
	MULTIPLY BY			
Crude Oil*	0.136	7.33	49.8	0.0201
Motor Spirit	0.118	8.45	43.2	0.0232
Kerosene	0.128	7.80	46.8	0.0214
Gas/Diesel	0.133	7.50	48.7	0.0205
Fuel Oil	0.149	6.70	54.5	0.0184

*Based on world average gravity (excluding Natural Gas Liquids)

APPROXIMATE CALORIFIC EQUIVALENTS

One million tons of oil equals approximately:	Heat units and Other fuels expressed in terms of million tons of oil equivalent	million tons of oil
Heat Units		
41 million million BTUs	10 million million BTUs approximates to	0.24
415 million therms	100 million therms approximates to	0.24
10,500 Teracalories	10,000 Teracalories approximates to	0.95
Solid Fuels		
1.5 million tons of coal	1 million tons of coal approximates to	0.67
4.9 million tons of lignite	1 million tons of lignite approximates to	0.20
3.3 million tons of peat	1 million tons of peat approximates to	0.30
Natural Gas (1 cub. ft = 1,000 BTUs) (1 cub. metre = 9,000 kcals)		
1.167 thousand million cub. metres	1 thousand million cub. metres approximates to	0.86
41.2 thousand million cub. ft	10 thousand million cub. ft approximates to	0.24
113 million cub. ft/day for a year	100 million cub. ft/day for a year approximates to	0.88
Electricity (1 kWh = 3,412 BTUs) (1 kWh = 860 kcals)		
12 thousand million kWh	10 thousand million kWh approximates to	0.82

One million tons of oil produces about 4,000 million units (kWh) of electricity in a modern power station.

Prices and Cost
US$1/million BTU = US$41 per TOE

THE WORLD BANK
Washington, D.C. 20433
U.S.A.

Office of the President

July 11, 1980

MEMORANDUM TO THE EXECUTIVE DIRECTORS

Subject: Energy in the Developing Countries

1. In January 1979, when the Bank's Accelerated Program for Petroleum Production was approved, I undertook to keep the Board informed of the progress of our work in what was then a virtually new field of activity for the Bank, particularly in respect of petroleum exploration. Since then, the energy situation of our developing member countries has become increasingly precarious. For the large majority of them that import oil, the imports of this vital commodity is absorbing resources that were, at least, barely sufficient to sustain their development objectives and to achieve a modest rate of increase in per capita income. With the prospect of a continuing rise in the real price of oil during the coming decade and beyond, a massive effort is needed in these countries to reduce dependence on oil imports. This requires increasing domestic supplies of energy to the fullest extent practicable and measures to improve the efficiency of energy use. Developing countries that are oil or gas exporters also need a well-integrated energy strategy because, for many of them, domestic production will decline in the absence of new discoveries.

2. The changed circumstances required more than a status report on the Bank's Accelerated Program for Petroleum Production. The attached paper, Energy in the Developing Countries, presents a broad survey and analysis of the energy prospects of developing countries over a period long enough for new policies affecting energy production and consumption to bring about significant changes in the supply of and demand for energy. In light of this analysis the Bank's program of assistance in the energy sector has been re-examined.

3. The paper:

- Summarizes the energy potential of developing countries during the 1980s, including the prospects for exploiting some of the newer technologies;

- Reviews policies for energy demand management, their application in key consuming sectors, and the potential for savings;

- Outlines the energy investment needs of developing countries during the decade of the 1980s;

- Reviews the progress of the Bank's work in energy to date; and

- In light of this analysis, points to the need for an enlarged program for FY81-85.

4. A sizeable reduction in the petroleum import requirements of the oil-importing countries during the decade is not only highly desirable but achievable. It will require a substantial expansion of energy investments, strengthening of planning and operating institutions, and determined efforts by governments to provide incentives for greater efficiency in energy use. The developing countries will need technical and financial assistance in this expanded effort from the Bank, other multilateral institutions and bilateral aid agencies. The proposed Bank program would further increase our support for this sector, particularly in areas such as oil and gas exploration and development, energy conservation, renewable sources of energy and coal, where the Bank is playing a major role and for which other sources of official assistance are likely to expand only slowly. But the requirements of this sector are so large that the Bank's presently planned resources will not be adequate if we are to continue to provide reasonable support to such other priority development objectives as agriculture and rural development, health and water supply, education, structural adjustment, urban and industrial development. We therefore propose to explore, as was suggested in the communique of the Venice Summit, whether the establishment of an energy affiliate or facility would provide additional financing for energy investment in the developing countries. We will report to the Board on the progress of these explorations shortly after the end of the year.

Robert S. McNamara

ENERGY IN THE DEVELOPING COUNTRIES

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GLOSSARY

The collective terms used to describe various energy groups are poorly defined, and several meanings for similar terms can be found in the literature on the subject. Collective terms used in this report are defined as follows:

Conventional Energy. Energy sources which have hitherto provided the bulk of the requirements for modern industrial society, i.e., coal (including lignite and peat); petroleum (including fuel oil, gasoline, kerosene, diesel fuel, natural gas and liquefied petroleum gas); and electricity generated by burning one or other of these fuels, or from hydro or nuclear power. Wood is not included in this category although it was extensively used in the past, and still is to some extent, for industrial purposes.

Commercial Energy. Any energy form sold in the course of commerce or provided by a public utility. The terms is virtually synonymous with Conventional Energy. Wood and other traditional fuels (see below) are not included although they are widely traded.

Primary Energy. An energy form in which there has been no chemical transformation before use. The term is of significance principally in relation to electricity generation, where hydropower is regarded as primary energy and thermal-generated power as secondary energy. Nuclear power is commonly referred to as primary energy although this does not accord with a strict interpretation of the definition.

Renewable Energy. An energy form, the supply of which is partly or wholly regenerated in the course of the annual solar cycle. Thus solar and wind energy, hydropower, and fuels of vegetable origin are regarded as renewable; mineral fuels and nuclear power are not.

Biomass Fuels. Combustible material of vegetable origin, for example wood, charcoal, corn cobs, cotton sticks, rice husks, dung cakes.

Traditional Energy. Those energy forms generally used in "traditional" or pre-industrial societies. They are largely synonymous with biomass fuels and the term is generally regarded as excluding mineral fuels and hydropower, despite the fact that water wheels have been in use for over 1,000 years.

Terms used in the report to describe particular forms of energy or procedures are defined as follows:

Enhanced Recovery, or Secondary Recovery. Methods of extracting a higher proportion of crude oil from a reservoir than can be obtained initially by using the natural energy of the reservoir.

Heavy Oil. Crude oil of high viscosity which in many cases prevents its being recovered from wells by normal methods.

Liquefied Natural Gas (LNG). Methane gas, liquefied by refrigeration to -161.4° C (-258.5° F).

Liquefied Petroleum Gas (LPG). Propane and butane gas liquefied, at ambient temperatures by pressure, or refrigerated to -45° C (-50° F) at atmospheric pressure.

Natural Gas. Any hydrocarbon or mixture of hydrocarbons occurring in a gaseous state at ambient temperature and pressure (principally methane).

Oil Shale: Sedimentary rock containing solid organic matter that can be extracted in liquid or gaseous form by heat.

Recoverable Reserves. Reserves of oil and gas recoverable from known reservoirs, with existing technology, under present economic conditions.

Ultimate Recoverable Reserves (URR). The total amount of oil and gas recovered and believed to be recoverable from both discovered and undiscovered reservoirs, in the light of probable improvements in technology, and based on a geological evaluation of a particular area or territory.

Retrofitting. Installing an energy saving device or process (or an alternative type of boiler) after a plant has begun operating.

Synthetics, or Synthetic Fuels. Fuels derived by chemical or other industrial processes from biomass, coal or petroleum.

Tar Sands (also known as "Oil Sands"). Sand and sandstone impregnated with heavy oil.

ABBREVIATIONS

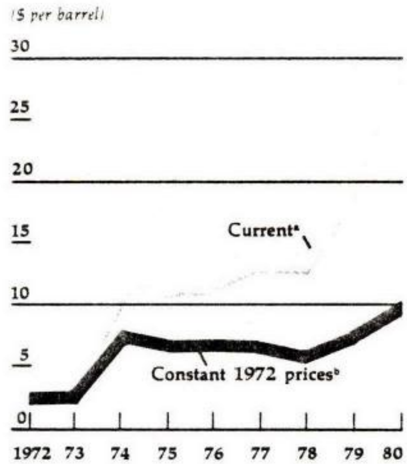
boe	:	Barrel of oil equivalent
Mbdoe	:	Million barrels per day of oil equivalent
MTOE	:	Million metric tons of oil equivalent
MTCE	:	Million metric tons of coal equivalent
TPY	:	Metric tons per year (output of coal plant)
Kcal	:	Kilocalorie (1,000 calories)
kW	:	Kilowatt (1,000 watts)
MW	:	Megawatt (1,000 kW)
GW	:	Gigawatt (1,000 MW)
TW	:	Terawatt (1,000 GW)
kWh	:	Kilowatt hour
GWh	:	Gigawatt hour
tce	:	Metric ton of coal equivalent

Chapter I: PERSPECTIVE FOR THE 1980s

1.01 It is now generally accepted that the energy problem of the 1970s was no passing phenomenon but marked the end of an era of cheap coal and oil, and the transition to high cost energy. In real terms the price of oil is now more than five times what it was in 1972 (see Figure 1) and World Bank projections for the years to 1990 indicate an annual increase of 3 percent a year. Now that energy is no longer cheap, it ranks in importance with the classical factors of production--land, labor and capital--and its supply and cost must be given due weight in the plans of economic managers at all levels. These considerations apply not only to forms of energy that are traded internationally, but also to energy that is produced and consumed domestically, and to traditional as well as commercial fuels, because the prices, availability and consumption levels of all forms of energy are inextricably interrelated. Over the next two decades the increased price of oil is expected to cause significant changes in the sources of supply, a large increase in investment in energy production to reduce dependence on imported oil, and greater efforts to make energy use more efficient.

1.02 Energy consumption in the developing countries accounts for a small part of the world total, but has been growing much faster. 1/ During the 1980s commercial consumption in these countries is projected to grow at 6.2 percent a year, somewhat more slowly than in the years before the oil price increases starting in 1973. During the 25 years before then, the relationship between the annual GNP growth of developing countries and their energy demand was about 1:1.3; this ratio dropped to about 1:0.8 during 1975-80. The continued rise in the real price of oil projected for the 1980s will tend to dampen the growth of energy demand, but unless there are vigorous conservation efforts the relationship between GNP growth and energy demand during the 1980s is likely to be closer to the historical trend than in recent years.

Petroleum prices, 1972–80



a. OPEC government sales prices weighted by OPEC output.
b. Deflated by manufactured export prices.

1.03 It is obviously a matter of great urgency that all countries take effective measures to reduce their energy consumption, but no country can afford to wait for a unified global effort. For the developing countries it

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1/ In this report, except where otherwise noted, "developing countries" refers to all countries eligible to borrow from the World Bank Group, as listed in Secretary's Memorandum SecM80-533, July 1980, other than China, on which the necessary data are not yet available, and Iran and Iraq, which are classified as capital surplus oil exporting countries in World Development Report, 1980. Under this definition, Lao People's Democratic Republic, Romania, Socialist Republic of Viet Nam and Yugoslavia are grouped among the developing countries.

is crucial both to continue and to expand efforts to use energy efficiently and to increase production. They have little margin to tolerate waste, their energy requirements are growing rapidly, and the achievement of their long-term development objectives depends on accommodating to the new energy situation. Although their consumption of commercial energy is relatively small, they are in a sense better placed to adjust their use of it than the industrialized countries, in that they are less committed to a capital stock and life style evolved in an era of cheap coal and oil. But they are hampered by inadequate information about resources and uses. Most of them also lack experience in commercial fuel production. The large majority have not yet tapped their own resources to any considerable degree and there is great scope for reducing dependence on imports.

Table 1: WORLD COMMERCIAL ENERGY CONSUMPTION, 1975-1990
(Million barrels a day of oil equivalent)

					Average Annual Growth (percent)		
	1975	1980	1985	1990	1950-74	1975-80	1980-90
World	122.1	137.8	166.0	201.5	5.0	2.5	3.9
Developing Countries	13.9	16.7	22.3	30.6	6.9	3.7	6.2
Oil Importing Developing Countries	9.3	11.1	15.0	20.5	6.9	3.6	6.3

Sources: Data underlying World Development Report, 1980, Table 2, pp. II-67; World Development Report, 1978, Table 19, p. 20; UN, World Energy Supplies, 1950-74, UN Statistical Papers Series J, No. 19 (New York: UN Department of International Economic and Social Affairs, 1974).

1.04 In designing policies to help resolve its energy problems, every country faces a unique set of conditions, including its level of income and degree of industrialization, its energy resource endowment, the relative importance of commercial and traditional fuels, its degree of dependence on oil imports, and other factors. But since the rise in the price of petroleum, the degree of dependence on petroleum imports has become the most important single factor.

1.05 The oil importing developing countries (OIDCs) face particular problems in maintaining their economic progress in the new era. As well as having to adapt their long-term investment plans to the higher cost of energy, many of them are finding acute difficulty in financing their present imports of petroleum. The cost of their net oil imports, in constant dollars, has risen almost ten-fold in the past decade and unless a major effort is made to reduce dependence on oil imports it is expected to more than double again by 1990 (see Table 24). Commercial energy consumption in these countries is projected to grow from 11.1 million barrels of oil equivalent per day in 1980 to 20.5 mbdoe in 1990, while their production, on present estimates, is expected to grow from 6.7 mbdoe to 13.3 mbdoe. Even if their domestic production could be increased further, there would still be a substantial gap which must be closed by fuel imports or by more efficient use of energy. The alternative is reduced GDP growth.

1.06 Many of the net oil exporters among the developing countries face similar problems in adjusting their economies to higher energy prices. Most of them need more capital than they can provide from their own savings. While their oil exports lessen the balance of payments constraint, they too must use energy as efficiently as possible, to maximize their export earnings and to extend the productive life of their reserves. Higher energy prices also affect their comparative advantage, investment requirements and intersectoral priorities.

A. An Energy Classification of Developing Countries

1.07 Table 2 lists oil importing developing countries according to the share of imported oil in total consumption of commercial energy. 1/ The classification is based on 1978 data, and the position of some countries listed has changed since then. Cameroon and Guatemala are becoming net exporters of oil, Bolivia has become a net importer, and Peru and Tunisia are on the verge of becoming importers. The Table indicates that in 1978:

-- 29 developing countries with a total population of over 1,500 million were net exporters of oil. Several of them (notably China, Indonesia and Nigeria) have large populations which could absorb most of their exportable surplus in the next decade unless significant new discoveries are made or alternative sources developed.

-- The vast majority (99) of the developing countries depend in varying degrees on imported oil. Some, notably Chad, Ghana, Ivory Coast and Pakistan, have the potential to become self-sufficient within this decade. Others, such as Brazil, Republic of Korea and Turkey, have a growing demand for oil and could become increasingly dependent on imports unless they develop alternative sources.

-- Among the 99 import-dependent countries are 64 countries, including some of the poorest, that depend on imports for

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1/ The Table also lists the capital surplus oil exporting countries, which are not included with other developing countries elsewhere in this report, and certain oil importing countries that are not members of the World Bank.

more than 75 percent of their commercial supplies. Their energy potential is not well known. Even small discoveries of oil, or the development of alternative sources of energy on a relatively small scale, could substantially reduce their dependence on imports.

1.08 Table 2 also shows countries which are already seriously short of fuelwood or depend heavily on fuelwood and other traditional sources of energy. They include a large majority of the low income countries, 1/ and most of those low income countries which are almost totally dependent on oil imports for their supply of commercial energy. These are the countries that face a double energy crisis.

B. Energy Policies

1.09 The appropriate energy policies differ among developing countries. Among those that import oil, middle income countries, especially those that are already semi-industrialized, share many of the energy problems of the developed countries. The switch from traditional to commercial forms of energy has already largely taken place, although there remain areas or pockets in which traditional forms of energy still dominate. These are the countries with fast rates of economic growth, whose energy requirements oblige them to buy large quantities of oil on the world market. Most of their commercial energy is used in industry, power generation and transport. These countries have been able to finance their imports by a combination of expanded exports and large foreign borrowings, and some of them have taken appropriate price measures to reduce the growth of demand for oil. They have been able to maintain reasonable, albeit reduced, rates of growth while beginning to make essential adjustments in the structure of their economies. Uncertainties about future markets for their exports, the availability and price of oil, and the extent to which further net foreign borrowings will be prudent, emphasize the need for these countries to exploit domestic resources more fully and to formulate policies and programs to maximize the efficiency with which commercial energy is used.

1.10 Low income countries derive a half or more of their total energy from wood and agricultural or animal wastes. But many of them depend heavily on petroleum for commercial energy, and are short of the resources needed to develop their own energy supplies. They too must be concerned with the energy efficiency of their development since investments made today will determine their energy requirements as modernization accelerates. One of the difficult choices they face is how to stop the rapid depletion of forests and soil fertility without unduly stimulating the use, and therefore the import,

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1/ Middle income developing countries are those with a GNP per person of US$360 and above in 1978; low income developing countries are those with a GNP per person below US$360 in 1978.

Table 2: AN ENERGY CLASSIFICATION OF DEVELOPING COUNTRIES

NET OIL IMPORTS AS % COMMERCIAL ENERGY DEMAND b/	NET OIL EXPORTING DEVELOPING COUNTRIES: OPEC Members	NET OIL EXPORTING DEVELOPING COUNTRIES: Non-OPEC	OIL IMPORTING DEVELOPING COUNTRIES a/: 0–25%	26–50%	51–75%	76–100%	
	ALGERIA *GABON* *IRAN* *IRAQ* *KUWAIT* *LIBYA* *QATAR* *SAUDI ARABIA* *UNITED ARAB EMIRATES* *VENEZUELA*	*BAHRAIN* *BOLIVIA* *MALAYSIA* *MEXICO* *OMAN* *PERU* *ROMANIA* *SYRIAN ARAB REP.* *TRINIDAD AND TOBAGO* *TUNISIA*	*ARGENTINA* *COLOMBIA* Korea, Dem. Rep. South Africa	*CHILE* Mongolia *YUGOSLAVIA*	*ALBANIA* *BRAZIL* Korea, Rep. of Lebanon *TURKEY*	Bahamas *BARBADOS* Costa Rica *CUBA* Cyprus Dominican Rep. Fiji *GUATEMALA* Guyana Ivory Coast Jamaica Jordan Malta	Mauritius Nicaragua Panama Papua New Guinea Paraguay Portugal Suriname Uruguay
COUNTRIES WITH ACTUAL OR POTENTIAL FUELWOOD PROBLEM c/	*ECUADOR* *INDONESIA* *NIGERIA*	*ANGOLA* *BURMA* *CHINA* *CONGO, PEOPLE'S REP.* *EGYPT* *ZAIRE*	*INDIA* Viet Nam, Zimbabwe	*BANGLADESH* Botswana Mozambique *PAKISTAN* Zambia	*AFGHANISTAN* Burundi *GHANA* Malawi Rwanda	Benin Bhutan *CAMEROON* Cape Verde Is. Central African Rep. Chad Comoros El Salvador Eq. Guinea Ethiopia Gambia, The Grenada Guinea Guinea–Bissau Haiti Honduras Kampuchea, Dem. Kenya Lao PDR Lesotho Liberia Madagascar Maldives Mali	Mauritania *MOROCCO* Nepal Niger *PHILIPPINES* Sao Tome and Principe Senegal Sierra Leone Solomon Is. Somalia Sri Lanka Sudan Swaziland Tanzania *THAILAND* Togo Uganda Upper Volta Western Samoa Yemen Arab Rep. Yemen PDR
POPULATION (IN MILLIONS)	320	1200	800	210	245	395	

Countries shown in *ITALICS* are oil and/or gas producers. Table based on US World Energy Statistics 1978 (except for Bhutan, Botswana, Lesotho and Swaziland whose position in the Table is estimated) and staff estimates of fuelwood situation. Population data from World Development Report, 1980 rounded to nearest 5 million.

a/ Excluding countries with 1978 per capita GNP above $3000 and countries with populations of less than 0.5 million that are not members of the World Bank.

b/ Imports 1978

c/ Includes two categories of countries: firstly, those in which according to Bank staff estimates the depletion of forests is already causing serious ecological problems; secondly, countries in which at least one-third of total energy demand is met by traditional fuels and the country faces potential ecological problems as demand for fuelwood increases with population growth. Countries were placed in this category if estimated annual consumption of fuelwood could not be sustained through the year 2000 without damage to the ecology at a level of 0.75 m^3 per capita where income per head (in 1978) was below $300, falling linearly to 0.50 m^3 at $600 and zero at $900.

of petroleum. Essential elements of the solution are afforestation, small hydroelectric installations, the more efficient design of cooking stoves and more use of coal. In the longer term, local applications of solar, biomass and other renewable forms of energy hold promise of more abundant energy in rural societies at lower economic and environmental costs.

1.11 Some poor countries such as India have a large industrial base and therefore share some of the problems of the middle income countries, while some of the latter have considerable populations still largely dependent on traditional fuels. The degree of dependence on imported oil also varies widely among countries at similar income levels. Other differences among countries have a bearing on their ability to plan and administer rational energy policies. Some, for example, have been producing coal, oil or natural gas for years and possess national companies with considerable experience in the industry. Others have weak or inexperienced institutions which need strengthening if they are to be capable of planning an energy strategy, advising government about the choice of investments and the management of demand, and informing and educating the public about the importance of conserving energy.

C. Investments in Energy Production

1.12 Between 1966 and 1975, the developing countries invested about US$12 billion a year (in 1980 dollars) on average in commercial energy production and transformation, mostly electricity. This represented about 5 percent of their total investment and 1.3 percent of GNP. In 1980 their investment in electric power, coal and petroleum production and refining is estimated at US$34 billion, almost triple the average of the earlier period.

1.13 A breakdown by source of the oil importing developing countries' estimated investments in commercial energy development in 1980 is given in Table 3, together with estimates of their requirements for the first and second half of the 1980s. The projections of demand on which these estimates are based are consistent with the "high" GNP growth rates projected in World Development Report, 1980. The estimates also take account of the historical growth of investment and production. Electric power production in developing countries grew at an average annual rate of 10.1 percent throughout the period 1950-78, while installed capacity grew at 9.7 percent. During the latter part of the period (1973-78) these rates were lower, at 8.3 percent and 7.3 percent, respectively, and future growth has been projected at similar rates; the required investment in power production has been derived from these projections. The figure for investment in oil is what is needed to raise the oil importing developing countries' production from the present level of 1.7 million barrels a day in 1980 to 3.3 million in 1990 (Table 6), while compensating for the depletion of existing fields during the decade. The investment figures for coal and natural gas also assume a substantially increased effort to raise production by the end of the decade. Gas production, in daily barrels of oil equivalent, is projected to rise from 0.9 million in 1980 to 1.2 million in 1990, while coal production is projected to rise from 2.2 million bdoe to 3.1 million bdoe.

Table 3: OIL IMPORTING DEVELOPING COUNTRIES: PRINCIPAL INVESTMENT REQUIREMENTS IN COMMERCIAL ENERGY, 1980-90 /a
(Billion 1980 US dollars)

	Estimate 1980	Annual Average 1981-85	Annual Average 1986-90	Average Annual Percentage Growth Rate 1980-90
Electric Power /b				
Thermal	8.0	11.8	15.4	9.1
Hydro	9.2	13.5	15.1	6.8
Nuclear	1.2	2.1	8.8	30.4
Other	0.1	0.1	0.4	20.3
Subtotal	18.5	27.5	39.7	10.7
Coal /c	0.5	0.7	1.5	15.8
Oil /d				
Exploration	0.5	1.0	1.5	11.6
Development	2.1	2.5	3.2	4.3
Subtotal	2.6	3.5	4.7	8.2
Gas /e	1.0	1.7	2.7	14.2
Alcohol	0.5	0.9	1.2	12.4
Fuelwood	0.5	0.6	1.3	13.6
Refineries /f	1.0	1.8	2.3	11.8
Total	24.6	36.7	53.4	10.9
Note:				
All Developing Countries	34.4	54.4	82.2	12.3

/a Based on Case 1 projections, which are described in Chapter II below.
/b Includes cost of transmission and distribution. Estimates assume that capacity requirements will grow at the same rate as in 1973-78.
/c Based on the investments required to develop coal production from 160 million tons of coal equivalent in 1980 to 230 million tce in 1990.
/d Based on the investments required to develop oil production from 1.7 million barrels of oil a day in 1980 to 3.3 million bdo in 1990.
/e Based on the investments required to raise gas production from 0.9 million bdoe in 1980 to 1.2 million bdoe in 1990.
/f Estimates assume capital requirements will grow at the same rate as in the recent past.

Source: Bank staff estimates.

1.14 The investment requirements shown in Table 3 are very large, amounting to 2.3 percent of the developing countries' GNP in 1980 and 3.2 percent of that projected for 1990. Even so, they do not take account of the additional investment that would be needed if the developing countries made a maximum effort to exploit their energy resources. The technical and economic case for doing so, and the related investment requirements, are considered in Chapter II. Financing such large investments will make heavy demands on domestic savings and require a massive infusion of external capital. But the oil importing developing countries face even larger expenditures on oil imports (US$50 billion in 1980 alone) and the economic return on energy investments is likely to be high.

1.15 The large scale of investment requirements in energy means that careful consideration has to be given to meeting future demand at the least cost, and determining priorities among various sources of supply. For any individual country, investment requirements and priorities depend on resource availability, relative costs, possibilities for substitution among fuels, market competition among fuels and the need for related investments. The relative costs of primary sources of energy for generating steam, for example, have already shifted significantly; the costs of developing a particular fuel vary widely from location to location; and the technology is continually changing. But though it is not possible to decide, a priori, the optimal resource development strategy for an individual country, it is probable that in the great majority of cases substantial savings would be gained by substituting domestic sources for imported oil. This point is illustrated by Table 4 which compares current estimates of the costs of the principal domestically produced fuels with their imported equivalents. Further details are given in Annex II.

1.16 Planning for investment in either the production or use of alternative energy sources must take into account their widely varying needs for associated infrastructure. For example, few developing countries can quickly take advantage of the wide price differential between imported coal and fuel oil because they lack port facilities, coal handling equipment, specialized surface transport, and coal burning facilities, all of which require heavy investment. Similarly, if indigenous resources displace residual fuel oil produced in a local refinery, investments in cracking plant may become essential to produce light products. Investments in storage and port handling facilities for large tankers could pay off quickly in many developing countries, by enabling them to take advantage of freight differentials between large and small tankers, which can be as high as US$4-5 per barrel of crude oil.

D. Management of Energy Demand

1.17 All countries can substantially improve the efficiency with which energy is used. For the oil importing developing countries this is particularly important since it would save imports. Indeed, with effective demand management and conservation policies, supported by appropriate fiscal,

Table 4: COMPARATIVE COSTS OF DOMESTICALLY PRODUCED FUELS FROM DIFFERENT SOURCES /a
(1980 US dollars per barrel of crude oil equivalent)

	Range of Domestic Prices	Imported Equivalent
Primary Energy		
Crude Oil	6.00 to 15.00	30.75 /b
Natural Gas	2.25 " 11.00	27.00 /c
Coal	4.50 " 15.00 /d	14.00 /e
Secondary Energy		
Derived from Crude Oil		
Gasoline - Primary Distillate	9.40 " 21.00	43.50
- Cracking of Fuel Oil	11.00 " 21.00	43.50
Kerosene	11.30 " 25.40	46.00
LPG	10.00 " 25.00	42.50
Fuel Oil	7.20 " 13.50	27.45
Derived from Coal		
Gasoline	40.00 " 60.00	43.50
Synthetic Fuels		
Ethanol from Molasses/ Sugarcane	25.00 " 45.00	43.50 /f
Shale Oil	25.00 " 35.00	30.75
Renewable Energy		
Firewood	8.00 " 20.00	46.00 /g
Charcoal	30.00 " 80.00	46.00 /g

/a Based on delivered cost to major consumers.
/b Based on posted price for Saudi Arabian Light Crude, 1st June 1980.
/c Based on imports of liquified natural gas or fuel oil.
/d Includes cost of infrastructure.
/e Cost of imported steam coal delivered to a coastal location.
/f Cost of imported gasoline.
/g Cost of imported kerosene.

Source: Bank staff estimates based on sources indicated in Annex II.

pricing and regulatory measures, the oil import bill of these countries in 1990 could be about 25 percent lower than if present trends continue. The greatest scope for raising efficiency is in the main energy consuming sectors such as industry and transport. Improved operating and maintenance procedures, training of staff and the installation of energy saving devices can yield significant savings comparatively quickly. Chapter III considers these possibilities, together with longer-term questions concerning the choice of industries and industrial processes, and the planning of transport systems, in order to make the most effective use of energy.

E. External Financing for Energy

1.18 It is by no means clear that the very large investment requirements for energy development in the oil importing developing countries will be met. In the past, capital for this purpose has come mainly from supplier credits, commercial banks, and other private sources. Commitments and disbursements of external loans for energy development in 1978, the latest year for which data on private lending are available, are shown in Table 5 below. Three-quarters of the loan disbursements in that year were from private sources, and about 80 percent of the total loan disbursements were for electric power, which has long attracted a substantial flow of capital from both public and private sources. There has been little external financing of coal, which is likely to be one of the main sources of incremental fuel in the next decades. Oil and gas development in oil importing developing countries that are already producers has been financed largely by private external capital. Although private sources are expected to continue playing the main role, additional financing from public sources will be required, especially for exploration. Many of the oil importing developing countries may have deposits of significance for their own economies but not for world supplies or trade. In many of them, too, private foreign investment may be inhibited by considerations of creditworthiness or other factors.

1.19 Commitments of Official Development Assistance and loans from multilateral agencies are estimated at about US$6.3 billion in 1980, compared with US$5.6 billion in 1979. Estimates suggest that a significant shift is taking place away from electricity financing, which appears likely to account for two-thirds of the total in 1980, the balance being mainly for fossil fuels. Funds for developing renewable sources and for technical assistance are also increasing, although the amounts are still small. The Asian and Interamerican Development Banks, and the OPEC Fund, will be reviewing their lending programs for energy during the coming months. The UNDP and other UN agencies are increasing their energy-related activities. While a reordering of priorities appears to be taking place in favor of primary energy and of more technical assistance for predevelopment of fossil fuels and for renewables, the increase in commitments of official capital for energy, other than by the World Bank, is modest.

Table 5: EXTERNAL LOAN COMMITMENTS AND DISBURSEMENTS TO OIL IMPORTING DEVELOPING COUNTRIES FOR COMMERCIAL ENERGY DEVELOPMENT, 1978 /a

(Billion US dollars)

	Official		Private		Total	
	$	Percent	$	Percent	$	Percent
Commitments						
Coal	.04	57	.03	43	.07	100
Oil and Gas	.32	21	1.21	79	1.53	100
Electric Power	4.07	52	3.80	48	7.87	100
Total	4.43	47	5.04	53	9.47	100
Disbursements						
Coal	.02	50	.02	50	0.4	100
Oil and Gas	.19	13	1.23	87	1.42	100
Electric Power	1.64	28	4.20	72	5.84	100
Total	1.85	25	5.45	75	7.30	100

/a In current prices. Includes external loans made to 78 oil importing developing countries for energy industries (coal mining; oil and gas production, refining and transport; and electric power production and distribution). The official sources covered are bilateral and multilateral loans and export credits; the private sources covered are bonds, commercial bank loans and suppliers' credits.

Source: World Bank external debt statistics.

1.20 The World Bank accounts for almost half the total official commitments for energy development, and will lend an estimated US$3 billion for this purpose in 1980. For some activities, such as predevelopment work in oil and gas, exploration, or oil development that includes secondary recovery, it is virtually the only source of official capital. It is playing an increasing role in the development of renewable energy resources, with an initial strong emphasis on fuelwood development, and is becoming capable of providing assistance in energy planning, including the formulation of policies for energy development and conservation. The Bank's program will help to increase the flow of resources for energy development, including private funds and technical expertise. It is thus important that it expand its work and its lending operations in the energy sector as requirements continue to grow. The proposed role for the Bank in the 1980s is discussed in Chapter IV. Because of the constraints which exist on the scope of the Bank program in this sector, it is also proposed to study further the possibility of a special facility for energy, associated with the Bank.

Chapter II: PROSPECTS FOR ENERGY PRODUCTION IN DEVELOPING COUNTRIES

2.01 Table 6 shows the present production of energy by source, and projections for 1990, for the world as a whole, for the oil exporting developing countries and for the majority of developing countries which import oil.

Table 6: WORLD COMMERCIAL PRIMARY ENERGY PRODUCTION, 1980-90

	Million Barrels a Day of Oil Equivalent						Average Annual Percentage Growth, 1980-90		
			Developing Countries					Developing Countries	
	World		Oil Exporters		Oil Importers		World	Oil Exporters	Oil Importers
	1980	1990	1980	1990	1980	1990			
Oil	63.1	77.3	11.8	16.1	1.7	3.3	2.1	3.2	6.9
Gas	27.0	45.0	2.1	4.0	0.9	1.2	5.2	6.7	2.9
Coal	41.3	62.5	0.3	0.6	2.2	3.1	4.2	7.2	3.5
Hydro	3.7	6.8	0.1	0.6	1.8	3.5	6.3	19.6	6.9
Nuclear	0.9	4.2	(.)	0.2	0.1	1.0	16.7	n.a.	25.9
Unal-located & Other	1.8	5.7	(.)	0.7	(.)	1.2	n.a.	n.a.	n.a.
Total	137.8	201.5	14.3	22.2	6.7	13.3 /a	3.9	4.5	7.1

(.) Less than half the unit shown. n.a.: Not applicable.

/a Adjusted for Case 1 production estimates, described in paragraph 2.08.

Source: Bank staff estimates from data underlying World Development Report, 1980, Table 2, p. II-67.

2.02 Long lead times are required to bring investments in primary energy, particularly coal, nuclear and hydro electricity, into production. The projections of energy consumption and production in the oil importing developing countries show an increased deficit (Table 23 below). Investments in domestic energy production must therefore be expanded as soon as possible if import requirements in the late 1980s and 1990s are to be kept within feasible limits. Energy production is also capital intensive, and in all countries careful choices have to be made among potential sources of capital and energy to ensure that available capital, both domestic and external, is deployed so as to maximize economic benefits. Technologies are changing rapidly in response to the high price of oil, so that assessments of technical feasibility and economic returns will have to be kept under constant review.

A. Oil

2.03 Since the 1950s oil has been the dominant source of commercial energy in the world. Despite the renewed emphasis on the development of other sources of energy, including coal and nuclear, oil will continue to supply 35-40 percent of the world's commercial energy demand during the remainder of this decade, and a much higher share of the demand for commercial energy in oil importing developing countries.

2.04 Some of the latter are, or are becoming, petroleum producers (Barbados, Brazil, Chile, Colombia, Ghana, Guatemala, India, Ivory Coast, Morocco, Pakistan, Philippines, Thailand, Turkey and Yugoslavia) and could hope to become self sufficient within the next 10 years, or to reduce their dependence on imports significantly. The potential of the vast majority of the import-dependent countries has been explored at best superficially; enough to determine that large, easily exploitable reserves are not present, but not enough to establish whether there are smaller deposits that could make an important contribution to their own energy supplies.

2.05 The uneven distribution of presently known reserves partly reflects the pattern of past exploration activity (See Annex I). Over 75 percent of the world's proven oil reserves of about 640 billion barrels are located in the Middle East, North America and the centrally planned economies, and these areas account for an equal share (73 percent) of world oil production. The urgency of discovering new oil reserves (partly through increasing the pace of exploration activity in developing countries) is underlined by the fact that world oil consumption is now growing almost as fast as additional reserves are being developed.

Table 7: WORLD OIL PRODUCTION, 1979, AND PROVEN OIL RESERVES ON JANUARY 1, 1980
(Million barrels)

	Production during 1979	Gross Additions to Reserves in 1979	Total Reserves	Distribution of Reserves (Percent)
Asia, Pacific	1,055	385	19,000	3.0
Western Europe	827	327	24,000	3.8
Middle East	7,732	-268	362,000	56.6
Africa	2,450	1,630	55,000	8.6
Western Hemisphere	5,616	19,616	90,000	14.0
Centrally Planned Economies	5,160	1,165	90,000	14.0
Total	22,840	22,855	640,000	100.0

Source: Oil and Gas Journal, Annual Survey 1980.

2.06 In 1979, after allowing for a record high production level of 22.8 billion barrels, the world's proven oil reserves increased by a mere 15 million barrels (Table 7). Even this increase was made possible only by the discovery and development of substantial additional reserves in Mexico. In every other region, including the Middle East, proven reserves declined during the year. Although additional reserves were proven in a few oil importing developing countries (Brazil, Cameroon, and Ghana) the overall reserve position of the group deteriorated during the year from 32.8 billion barrels to 30.7 billion barrels.

2.07 Recent reports, among them that prepared for the Conservation Commission of the World Energy Conference in 1977 1/, indicate that the world's remaining ultimate recoverable reserves (URR) of oil are about 1,900 billion barrels 2/. BEICIP, the consulting arm of the French Petroleum Institute, has estimated the remaining URR of 84 developing countries other than OPEC members at about 81 billion barrels 3/ (4.4 percent of the world total) of which only 20 billion (24 percent) were considered proven. The breakdown of the URR by region and type of country is summarized below in Table 8.

Table 8: 84 DEVELOPING COUNTRIES: ESTIMATED REMAINING ULTIMATE RECOVERABLE OIL RESERVES /a
(Million barrels)

	Net Exporters		Net Importers					
			Producing		Nonproducing		Total	
	URR	Proven	URR	Proven	URR	Proven	URR	Proven
Africa	12,205	10,215	90	/c	13,730	0	13,820	/c
Asia	6,060	965	5,650	1,790	8,375	0	13,025	790
Latin America	..	..	16,675	4,950	5,510	0	22,185	4,940
Middle East	8,600	1,500	1,605	450	1,515	0	3,120	450
Total	26,865	12,680	24,020	7,190	29,130	0	52,150	7,180
Note: Proven Reserves as Percentage of URR	49			30		0		14

.. Not available.
/a Excluding OPEC members.
/c Less than 100 million barrels.

Source: Bureau d'Etudes Industrielles et de Cooperation de l'Institut Francais du Petrole (BEICIP), Petroleum Resources of Oil Importing Developing Countries, 1975. See also Annex 1.

1/ Pierre Desprairies, "World-wide Petroleum Supply Limits". Institut Francais du Petrole, 1977. The estimates made for the World Energy Conference are "an evaluation of the technical maximum that would make it possible to produce within the limit of a price of US$20 per barrel (in 1976 dollars) by year 2000."

2/ For a definition of URR (which does not include heavy oil and oil shale) see Glossary.

3/ Excluding deep offshore, 22 billion barrels, and giant fields, 14.7 billion barrels.

In oil importing developing countries, the ratio of proven reserves to remaining URR (14 percent) is much below the current world ratio of about 37 percent; the undiscovered potential, although small by world standards, is substantial in relation to their own consumption.

2.08 Table 9 gives two sets of estimates of oil production in the oil importing developing countries in 1990. At present, 19 of the OIDCs (listed in Table 2) are producing oil at the rate of 1.7 million barrels a day, up from 1.2 mbpd in 1977. By 1990 they should be able to raise production to 2.6 mbpd. This is the level in Case 1 shown in Table 9, which represents probable production in 1990. Allowing for the depletion of existing proven reserves, this would require proving and bringing into production the bulk of their presently estimated remaining URR. Experience in major producing countries suggests that this should be feasible, if there is adequate investment in exploration and production facilities. Prospects for additional reserves include second-phase discoveries in older established basins, since more intensive exploration is encouraged by the improved economic viability, at present and foreseeable prices, of small accumulations, better technology and exploration methods, offshore extensions of coastal basins and deeper drilling. Increases in reserves could also come from enhanced recovery methods, including the recovery of heavy oil, as described below. By 1990, this should enable countries that are now producing to raise their production by a further 400,000 barrels a day, provided an early start is made on enhanced recovery and additional investment can be financed. This level of production is included in Case 2 -- possible production in 1990.

Table 9: OIL IMPORTING DEVELOPING COUNTRIES: ESTIMATED OIL PRODUCTION, 1980-90
(Million barrels a day)

	1980	1990	
		Case 1	Case 2
	Estimated	Probable	Possible
Producers in 1980			
Normal	1.7	2.6	2.6
Enhanced Recovery	0	0	0.4
Nonproducers in 1980	0	0.7	1.5
Total Production	1.7	3.3	4.5

Source: Bank staff estimates.

2.09 Oil has been discovered in five oil importing developing countries that are not producers at present (Benin, Chad, Niger, Ivory Coast and the Sudan). Based on an analysis of these and 15 other oil importing developing countries where exploration is active and whose prospects of discovering oil appear promising, production of 0.5 to one million barrels a day by 1990 is considered feasible. In Case 1, the projected level of production in these twenty countries is 0.7 mbpd. A vigorous survey and exploration effort, and the rapid development of commercial discoveries, in the more promising of the remaining oil importing developing countries should make possible the production of up to one million barrels a day by the end of the decade. In Case 2, the projected level of production in the remaining countries is 0.8 mbpd, making total possible production of 1.5 million barrels a day by 1990 in OIDCs that are not now producing oil. This assumes that additional investment will be made early in the decade in countries where there is now no active exploration, with the objective of discovering and bringing into production 30 to 50 percent of the URR by the end of the century, compared with 12 to 15 percent by 1990 in Case 1. The bulk of the reserves discovered between now and 1990 would sustain production in the early 1990s. It is unlikely that any of the oil importing developing countries will be able to produce significant volumes of oil from oil shale or sand deposits before the end of this decade.

Exploration in Oil Importing Developing Countries

2.10 Over the past 10 years exploration has increased considerably worldwide, as shown in Table 10. However, the amount of geophysical and exploratory drilling activity in oil importing developing countries has not increased and in some areas there has been a decline. In 1978, geophysical work in OIDCs accounted for 10 percent and exploratory drilling for 2.5 percent of the world total respectively. Unless the level of exploratory activity can be raised soon, there is little chance of a substantial improvement in their domestic production during the coming decade, given the time needed to mount an exploratory campaign and develop a discovery to the point of starting commercial production. Some of the oil producing developing countries which formerly eschewed or severely limited the activities of private oil companies are now actively seeking their intervention in exploration. Examples are Argentina, Brazil, Chile, Pakistan and Turkey. If oil importing countries not now producing oil follow this trend, exploratory activity in those countries may increase during the 1980s. But to attract risk capital toward nonproducing countries whose potential the oil companies have evaluated as small, which the latter consider politically unstable, or which have legislative and contractual provisions that deter foreign participation, more purposive actions by governments and international lending institutions may be necessary.

Table 10: WORLD AND OIL IMPORTING DEVELOPING COUNTRIES: OIL PREDEVELOPMENT ACTIVITY, 1970 AND 1980

	Geophysical Activity (No. of party months)		Exploration Drilling (No. of wildcat wells)	
	1970	1978	1970	1978
World	6,155	8,354	10,029	15,258
Oil Importing LDCs				
Producers in 1980	855	709	271	332
Nonproducers in 1980	148	134	69	63
Total	1,003	843	340	395

Source: Petro-Canada - Petroleos de Venezuela: World Oil Supply Prospects, February 1980.

Capital Requirements in Oil Importing Developing Countries

2.11 The capital requirements of Case 1 in Table 9 are on the order of US$40 billion (in 1980 dollars) during the 1980s. In the early years about US$1 billion a year would be needed for exploration and US$2 billion a year for the development of reserves that it is assumed will be discovered in areas now under active exploration. In the latter part of the decade, expenditure would be stepped up to US$4-5 billion a year (in 1980 dollars) to bring into production more discoveries and to finance a continuing program of exploration for production in the 1990s.

2.12 The more ambitious program represented by Case 2 would require additional capital investment of US$10-20 billion during the decade. This would include a larger exploratory effort in the countries that are not now producing, and development, including enhanced recovery, of reserves already found in countries now producing oil. Additional investment would improve the chances of a rising level of production in the 1990s. It would also provide for a start to be made in developing and testing techniques for exploiting reserves of heavy oil, tar sands and oil shale. The prospects of producing oil from these resources in developing countries are discussed below.

2.13 Investment expenditures on this order--US$40-60 billion in 1980 dollars during the decade -- are large in relation to expenditures in recent years. But they are about equal to the sum which the oil importing developing countries will spend in 1980 alone on imports of oil (almost US$50 billion). The economic rate of return on domestic oil production, given present and projected international oil prices, is likely to be reasonably high. Hence, depending on their geological potential, OIDCs would be well advised to promote as large a program of oil exploration and development as their managerial, technical and financial resources permit.

Enhanced Recovery

2.14 Enhanced oil recovery from "depleted" fields is physically possible because under the initial regime of exploitation only some 10 percent to 30 percent of the oil deposit is typically recovered. The remaining oil must be recovered by artificial stimulation of the reservoir, for which a number of techniques have been developed. These consist of injecting water or gases, sometimes mixed with special chemicals, into the reservoir so as to flush the remaining oil toward the production wells. Heavy capital investment is required for injection wells, pumping equipment, water and gas separation and disposal equipment; at the new prices for energy it has become attractive to incur these expenditures. The Bank is involved in projects of this type in Colombia and Peru, and one in Ecuador is under consideration.

2.15 Between 30 and 50 percent of the future oil production in the US and Canada is expected to come from enhanced recovery, and such projects are being actively implemented, some with government assistance. In developing countries, by contrast, very few enhanced recovery projects are currently under consideration although production from older fields is declining. The potential for incremental oil production through enhanced recovery has not been systematically assessed in the developing countries. And even where such potential is known to exist, the financial return offered to foreign oil companies may not be large enough to justify the higher investment, particularly if the incremental production is expected to be modest. Developing countries' oil companies, on the other hand, generally do not have the technical expertise to undertake these projects.

2.16 The potential for incremental oil production through enhanced recovery should be systematically assessed. It is estimated that, except when the most sophisticated methods are used, the investment cost needed to produce oil through secondary recovery is about US$15,000 per daily barrel. As mentioned above, enhanced recovery could by 1990 contribute about 400,000 barrels a day to the supply of the oil importing developing countries; the capital expenditures required would be about US$6 billion.

2.17 Heavy oil and tar sands. The current oil price has more than doubled the world's recoverable oil reserves by making it economically feasible to exploit an increasing number of heavy oil deposits. Heavy oil is a loosely defined term which is generally taken to mean any crude oil of less than 20^{o} API (that is, with a specific gravity of .934 or more). World heavy oil reserves are probably much larger than known reserves of conventional crude oil; they are estimated to be as much as 3 trillion barrels of oil in place. This may also be compared with the estimated 450 billion barrels of conventional crude oil in place in Saudi Arabia. Appreciable quantities of heavy oil are produced in the normal course of oil industry operations in Canada, the US and Venezuela, but the greater part of the known reserves have not so far been exploited because they are difficult to extract from the reservoir rock. A substantial part of these reserves is in Canada and Venezuela, but several developing countries are known to have heavy oil deposits which have not been fully assessed (Colombia, Congo, Madagascar, Morocco, Peru, Senegal, Tunisia and Turkey -- see Annex Table I.2). How much of the world's heavy oils can ultimately be recovered cannot at present be determined accurately, but even a low recovery rate would yield a very large supply.

2.18 Some of the heavy oil can be recovered by conventional pumping, as in the past, or by enhanced recovery techniques whereby the oil is heated in the reservoir, either by injecting steam into the well, or by injecting air and then igniting and burning part of the oil in the reservoir. In both cases the heat so applied to the oil in the reservoir reduces the viscosity of the oil and allows it to flow into the wells from which it is recovered. Another system involves injection of carbon dioxide gas into the reservoir where it is absorbed by the oil; the gas causes the oil to expand and also reduces its viscosity. The Bank is financing an enhanced recovery program for heavy oil by this method in Turkey. All heavy oils are too viscous to be pumped any distance by pipeline and it is therefore usual to refine them at or near the production site. The refining process, which is an important part of the cost, includes cracking to upgrade the oil to lighter products, which are then blended again for transport by pipeline.

2.19 Tar sands, also known as "oil sands", are an extreme case of heavy oil occurrence. They consist of sands or sandstone impregnated with a heavy viscous asphaltic oil and are usually exposed at the earth's surface, or covered by only a thin overburden. The oil is immobile in the sand at normal surface temperatures and the only economical method of recovering the oil so far devised is to mine the sand and extract the oil by washing it with hot water. The only commercial exploitation of this type of deposit for oil production at the present time is in western Canada. Other deposits are known to exist in a number of countries, including Ecuador, Madagascar, Nigeria and Trinidad.

2.20 Investment costs for heavy oil are higher than for conventional oil development, on the order of US$15,000 to US$25,000 per daily barrel of production, as compared with US$10,000 per daily barrel of production for North Sea oil. For oil from tar sands, investment costs are in the range of US$25,000 to US$35,000 per daily barrel of production; the technological and managerial expertise for such projects is not widely available. These investment costs include the cost of the refining plant at or near the production site.

2.21 Heavy oils are expected to make only a small contribution of 200,000 barrels a day to supply in the oil importing developing countries in the latter part of the 1980s. The most likely countries include Colombia, Madagascar, Senegal and Turkey where resources have already been identified. Though tar sands in developing countries do not seem likely to be exploited during the coming decade, the present world prices for crude oil mean that many heavy oil projects are likely to be economically viable. Projects of this nature are likely to be beyond the technical and financial capacity of many developing countries, and hence will require assistance from international financial institutions and cooperation with international oil companies. The Bank has been assisting the Governments of Senegal and Turkey in developing heavy oil projects. There is also a growing degree of international cooperation within the oil industry in this field. An international conference sponsored by UNITAR took place in 1979 in Canada. Cooperation agreements have been signed between Canada, the US and Venezuela. Madagascar and the Province of Alberta have also begun cooperative efforts in this area, and Turkey is considering cooperation with Alberta and possibly Venezuela in the Bati Raman project.

Oil Shale

2.22 Production of oil from shale antedates the conventional petroleum industry. Oil shale constitutes a large low-grade resource of hydrocarbons that is exploited only to a limited extent at present. Oil shales are fine-grained sedimentary rocks containing solid organic matter which, on heating, disintegrate into oil and gas, but which do not contain any free oil. The liquid fractions resulting from heating shale resemble crude oil and can be refined to yield conventional petroleum products such as gasoline, diesel oil and fuel oil. At higher temperatures more light products, and also more gas, are formed. Oil shale can also be burned directly as a low-grade fuel in specially designed boilers, usually for power generation.

2.23 Oil shales are widely distributed and estimated reserves are very large. Reserves are usually classified in terms of the amount of oil obtainable by heating one ton of shale. The richer shales yield 25 to 100 US gallons of oil per ton of shale; the majority of deposits are leaner than that. In estimating reserves an arbitrary lower yield limit has been chosen. Table 11 (based on Annex I Table 3) identifies oil shale reserves containing over 3,000 billion barrels of oil with a yield of 10 US gallons per ton of shale and above. About 5-10 percent of these reserves are exploitable at present technology and prices. Relatively little exploration has been undertaken for oil shale deposits, and actual world reserves may be several times as large as those already identified.

Table 11: WORLD OIL SHALE RESOURCES

	Billion Barrels of Oil in Place	Distribution of Resources (percent)
Developing Countries		
Oil Importing Developing Countries	803	25
Oil Exporting Countries /a	131	4
Subtotal	934	29
Developed Market Economies	2,217	68
Centrally Planned Economies	113	3
World	3,264	100

/a Includes China, with 27.9 billion barrels.

Sources: "Budget d'Exploitation des Pyroschistes ou Schistes Bitumineux: Donnees Generales et Perspective d'avenir." Revue de L'institut Francais du Petrole, XXVIII, 1975. (Grade of resources listed is 10 gallons per ton and above). Mortveyev, A. K., Oil Shale Outside the Soviet Union: Deposits of Fossil Fuels (Boston, Massachusetts: H.G.K. Hall and Co.,1974). (No minimum grade for resources listed.)

2.24 Developing countries known to have large shale oil deposits are Brazil, China and Zaire. Countries with smaller but nevertheless potentially exploitable deposits include Burma, Jordan, Morocco, Thailand and Turkey. A pilot plant for oil extraction has been constructed in Brazil, and Morocco is considering a 250 MW shale burning power plant, as well as the establishment of a modified batch-retorting process for oil extraction. Jordan is also reported to be considering a shale-fired power station.

2.25 Mining and retorting represent a large part of the total cost of producing petroleum products from shale. About 80 percent to 85 percent of the shale is inert rock that is usually processed as close to the mine as possible in order to minimize transport costs. One process is being developed in the US for extracting the oil in situ without having to mine the bulk of the shale, but it is only appropriate for deposits of considerable vertical thickness, and recovers a much lower proportion of the total resource. Considerable technical difficulties are associated with such modified in situ extraction, and the underground preparation costs are also high. However, they reduce the problems of disposing of the spent shale above ground.

2.26 Shale oil is refined in a similar manner to conventional crude oil, which it closely resembles, to produce a similiar range of refined products. Because it is unstable in storage unless refined, it is usually refined fairly close to the production site.

2.27 Oil shale is extensively used directly for power generation in the Estonian Soviet Republic. The only plant in a developing country to use shale as fuel, in a mixture of 30 percent shale with 70 percent lignite, is at Seyitomer in Turkey. The low calorific value of the shale, as compared with bituminous coal and fuel oil, requires a very large furnace for a given output, and a capacity to handle large quantities of solid fuel. Ash disposal problems are similar to those in shale oil production.

2.28 Cost estimates relating to existing shale oil industries in China and the USSR are not readily available. The high-technology, capital-intensive techniques being used in the US may not be appropriate as models for some developing countries. Based on existing pilot projects, projected costs for plants in the US indicate an investment of around US$30,000 per daily barrel for a plant producing 50,000 barrels a day. Production costs in the 1980s are estimated to be of the order of US$25-35 per barrel of synthetic crude. 1/ Capital costs would tend to be higher in developing countries where large industrial facilities are generally more expensive to develop. Oil shale deposits have individual characteristics which will require pilot testing before full-scale development is undertaken. Plant trials are risky, given present technology, and capital requirements for investment in oil shale are high. But even while processing technologies are being further tested, developing countries with known reserves of shale, or good prospects for discovering oil shale deposits, should view survey and identification efforts to define oil shale prospects as a sound investment. It seems probable that suitable technologies will become operational and that costs will decline, making production economical against the projected increase in real oil prices. The Bank has provided financial assistance to Morocco for oil shale identification as a component in a loan for oil exploration, and similar assistance is planned in Mali and Somalia.

Refineries

2.29 Petroleum refineries are an essential link in converting crude oil into the refined petroleum products (such as gasoline, diesel fuel, kerosene, fuel oil and naphtha) needed by consumers. Their size and complexity vary widely. Large complex refineries in developed countries have a primary processing capacity in the range of 100,000 to 600,000 barrels a day. Those in the developing countries, with some exceptions such as Brazil and Mexico, are generally of less than 100,000 barrels a day capacity and many are in the range of 20,000 to 50,000 barrels per day. Table 12 shows the distribution of world refining capacity among groups of countries.

1/ Based on Shell Group and Bechtel Corporation estimates adjusted for inflation.

Table 12: WORLD REFINING CAPACITY, JANUARY 1, 1980
(Million barrels per day)

	Primary Distillation Capacity	Secondary Refining Capacity /d
Developed Countries	48.7	27.4
Centrally Planned Economies	13.8	0.1
Capital Surplus Oil Exporters /a	2.4	0.7
Developing Countries		
Net Oil Exporters /b	6.0	2.4
Net Oil Importers /c	6.9	3.3
Subtotal	12.9	4.7
World	77.8	32.9

/a Iran, Iraq, Kuwait, Libya, Qatar and Saudi Arabia.
/b Algeria, Angola, Bahrein, Bolivia, Ecuador, Egypt, Gabon, Indonesia, Malaysia, Mexico, Nigeria, Peru, Syria, Trinidad, Tunisia, Venezuela and Zaire.
/c 46 oil importing developing countries.
/d Includes cracking capacity as well as product finishing plant.

Source: Oil and Gas Journal.

2.30 Refineries in developing countries are faced with special problems in producing a combination of products appropriate for domestic demand and in operating efficiently. First, most of them serve local markets which require a large proportion of light distillates; the product mix therefore includes a high proportion of gasoline, kerosene and diesel fuels. Demand for fuel oil in many developing countries is limited by a small industrial base, few heating requirements, or the use of other primary energy sources for generating electric power. The petroleum replacement programs launched by many countries are intended to replace fuel oil with hydropower, coal and gas, and their effect will be to increase the demand imbalance between light and heavy fuels. In world markets, too, the proportion of heavy crude in the overall crude supply is expected to increase. The action of producer countries, such as Mexico and Saudi Arabia, in requiring purchasers of light crude oils to purchase also a proportion of heavier crude, testifies to this trend.

2.31 Second, most developing countries' refineries are small, with a simple configuration consisting of distillation units with little or no capacity for converting heavy fuel oil into lighter products. For their raw materials, such refineries must use light crude oils, such as Nigerian, which normally command a 20-35 percent premium, or a "spiked" crude oil to which has been added a proportion of raw naphtha and gas oil, which costs appreciably more than the original crude, while fuel oil may have to be exported at distress prices. Moreover, the small size of operations does not permit economies of scale to be achieved. Table 13 compares typical configurations and operating costs in refineries in developing and developed countries.

Table 13: TYPICAL REFINERY CONFIGURATIONS IN DEVELOPING AND DEVELOPED COUNTRIES

	Typical LDC Refinery	World-Scale Refinery
Distillation Capacity: Million Tons/Year (Barrels/Day)	1 (20,000)	6 (120,000)
Investment Cost per Daily Barrel (1980 US Dollars)	4,450	2,100
Unit Investment Cost: 1980 US Dollars per Ton/Year of Distillation Capacity	89	42
Operating Cost, 1980 US Dollars per Barrel of Throughput /a	4.52	2.05

/a Includes a capital charge of 25 percent of investment cost, but excludes crude oil cost.

Source: Bank staff estimates based on information from engineering companies.

2.32 Third, in many developing countries refineries have difficulty in achieving reasonable utilization capacity because designs are inappropriate, equipment fails, or staff lack expertise in operating well designed and constructed facilities.

2.33 As a result of these factors, the cost of domestically refined petroleum products is often unnecessarily high, and oil import bills are also substantially larger than they would be if local production were more efficient and better balanced. Nevertheless, developing countries will have to rely increasingly on domestic refineries since the international oil companies operating from traditional export refining centers such as Rotterdam, the Caribbean and Singapore, are losing the ability to play a balancing role in the world market. New OPEC export refineries are unlikely to become a major source of refined products and, as such, a balancing factor in the international market, before the late 1980s or early 1990s.

2.34 The main solution to the demand imbalance problem in developing countries with refineries would be to install cracking facilities to convert the heavy fractions from crude oil into light products. The type, size and intended benefits of cracking plants should be carefully determined, as investment and operating costs vary widely among alternative technologies, the unit investments ranging from US$1,000 per daily barrel for thermal cracking, to US$5,000 per daily barrel for hydro cracking. Economies of scale can be important. In general, developing countries with large refining capacity, such as Argentina and Thailand, are best placed to install world-scale conversion plants. For smaller countries the development of regional refining and conversion centers would be advantageous, to exploit economies of scale and reduce transport costs. This option would also be attractive to countries whose demands for various types of products are complementary.

2.35 Developing countries which experience operating problems in their refineries should consider measures to bring their capacity utilization up to world standards. In countries where domestic oil production is expected to increase substantially, investment in new refining capacity may be warranted, beyond their domestic market requirements, to fill the expected international supply gap. Oil importing developing countries are estimated to require two to three million barrels a day of primary distillation capacity and about 1.5 to 2.0 million barrels a day of additional cracking capacity by 1990. Most of the additional cracking capacity is needed during 1981-85 and most of the additional distillation capacity during 1986-90.

2.36 In planning investments in refining capacity, the economics of all the various alternatives would have to be assessed case by case, taking into consideration alternative sources of supply. However, these types of projects generally yield high rates of return. Transport cost savings, resulting from a reduction in import/export flows, contribute significantly to their profitability. An estimated US$21-27 billion (in 1980 dollars) will be required for investment in refining capacity in the developing countries during the next ten years.

B. Natural Gas

2.37 The term "natural gas" refers to hydrocarbons, usually predominantly methane, which are found in a gaseous state in underground reservoirs. They may occur alone (nonassociated gas) or in conjunction with crude oil (associated gas). The latter occurs both as free gas above the oil (gascap) and dissolved in the oil (solution gas). Production of associated gas dissolved in oil depends on oil production, and is therefore interrupted whenever the latter is shut down for economic or other reasons. The use of such associated gas has therefore to be backed up by equipment that can use a substitute fuel (in the domestic market) or a supply of nonassociated gas (in the domestic market and for export). Nonassociated gas production depends on the structure and characteristics of the reservoir, and is therefore developed on the basis of the size of market and the overall viability of the project. Natural gas may contain substantial proportions of nonhydrocarbon gases as impurities. Most natural gases contain small proportions of heavier hydrocarbons, besides methane, which can readily be reduced to liquid form at the surface by refrigeration or compression. These so-called "wet gases" can be processed to produce natural gas liquids (NGL) otherwise known as natural gasoline or casing head gasoline, and liquefied petroleum gases (LPG) consisting of propane and butane.

2.38 Historically, oil had fundamental advantages over gas as a fuel; it could be transported easily, it could through refining yield a number of products which could serve different markets, and it has a higher energy content for a given volume. The physical characteristics of gas, particularly the difficulties of transporting it, limited its share in the growth of international energy trade. Until techniques were developed in the 1960s for ocean transport of liquefied natural gas, international trade depended on land pipelines. Gas development for domestic use in developing countries has also been limited because markets have rarely been sufficiently large and concentrated to absorb the high cost of pipelines and distribution facilities and hence make gas competitive with oil products (mainly fuel oil). Therefore, where no ready local market existed, associated gas has usually been flared and nonassociated gas discoveries have not been developed.

2.39 World natural gas reserves are presently estimated at over 455 billion barrels of oil equivalent (Table 14 and Annex I Table 1), which is 72 percent of proven oil reserves and 15 percent of proven coal reserves. More than 75 percent of the gas reserves are in North America, the Middle East and centrally planned economies, including China.

Table 14: WORLD ESTIMATED CURRENTLY PROVEN NATURAL GAS RESERVES /a

	Associated Gas		Nonassociated Gas		Total	
	Billion Barrels of Oil Equivalent	Percent	Billion Barrels of Oil Equivalent	Percent	Billion Barrels of Oil Equivalent	Percent
Industrialized Countries						
United States	11,970	9	25,450	8	37,380	8
Western Europe	7,480	6	18,610	6	26,100	6
Others	2,950	2	14,380	4	17,340	4
Subtotal	22,400	17	58,400	18	80,810	17
Centrally Planned Economies	18,030	14	150,000	47	169,000	37
OPEC	81,320	61	96,430	30	177,760	39
Non-OPEC Developing Countries	11,530	9	17,500	5	28,030	6
Total	133,280	100	322,330	100	455,590	100

/a In this table, centrally planned economies include China; "OPEC" includes all OPEC members.

Sources: BEICIP, 1980; Petroleum Economics, Ltd., 1979.

Until recently gas discoveries outside the US, Western Europe and the USSR have not been fully evaluated, and reserve estimates should be treated with caution. Over the past 10 years additions to gas reserves have been equivalent to additions to oil reserves (about 290 billion barrels) and on average twice the level of gas consumption. Some estimates put the world's ultimate recoverable gas reserves at least equal to those of oil (1,900 billion barrels) or roughly four times the gas reserves currently proven. The availability of associated gas, which is produced with oil, is better known. Table 15 shows that 40 percent of the gas produced in association with oil is flared.

Table 15: WORLD ASSOCIATED GAS PRODUCTION, 1978
(Million barrels of oil equivalent)

	Production	Flared	Percentage of Production Flared
Africa			
Nigeria /a	140	140	100
Gabon /a	10	10	100
Other	180	115	64
Subtotal	330	265	80
Latin America			
Mexico /a	130	20	15
Venezuela /a	110	20	18
Argentina	70	20	29
Other	80	60	-
Subtotal	390	120	31
Asia/Middle East	1,300	770	59
North America	770	40	5
Western Europe	80	60	75
Eastern Europe	620	130	21
Total	3,490	1,385	40

/a 1977 figures.

Sources: BEICIP, 1980; De Golyer MacNaughton: Petroleum Statistics 1979; Bank staff estimates.

2.40 From 1965-78, the share of natural gas in world energy consumption remained almost constant at about 18 percent. In 1978 world gas consumption was about 8,900 million barrels of oil equivalent, of which about 5,600 and 2,500 million boe were used by developed countries and centrally planned economies, respectively. In developing countries in that year natural gas accounted for less than 10 percent of the total consumption of primary commercial energy. Of their gas consumption of roughly 600 million barrels of oil equivalent, 175 million boe were used in Romania, about 220 million boe in Algeria, Argentina, Mexico and Pakistan, and another 180 million boe in 10 developing countries whose gas consumption was higher than 7 million boe/year. The balance was spread over a larger number of developing countries whose individual consumption did not exceed 1.5 million boe/year on average.

2.41 With oil production rising in the 1980s, more associated gas will be produced. Governments of producing countries are conscious of the enormous waste of associated gas and have taken steps either to reinject the gas, or to treat it in order to extract LPG and NGL. These measures should produce considerable volumes of LPG and NGL in the 1980s. On the basis of existing plans, availabilities for export from developing countries are currently expected to increase from about 105 million boe in 1978 to 545 million boe in 1990 for LPG, and from about 150 million boe to 650 million boe for NGL. Most of the incremental production would be in OPEC countries. Because existing markets for these products are limited, the disposal of the quantities available in the coming years may present problems. Developing producing countries that have potentially large domestic markets, notably Algeria, Indonesia, Malaysia and Nigeria, should thus consider increasing the use of LPG and NGL domestically, particularly for transport. Preliminary estimates indicate that if a systematic effort were made to recover natural gas liquids in the developing countries presently considered to have natural gas potential, NGL and LPG could contribute about 700 to 1,000 million barrels of oil equivalent to domestic supplies in 1990. 1/ Most of these supplies would be in countries that already produce oil.

2.42 Current projections for natural gas supply and demand in industrialized countries (excluding the USSR and Eastern Europe) indicate that their total production is expected to remain at 5.5 to 5.6 billion barrels of oil equivalent a year until 1990, the main reasons being the expected decline of US production and the modest growth of North Sea production, which should reach its peak between 1985 and 1990 unless recent discoveries are proven and developed more rapidly than expected. Consumption in the US, Japan and Western Europe should increase from 6.0 billion boe in 1980 to about 7.3 billion boe in 1990. A substantial market for LNG imports from developing countries should therefore develop in the 1980s and thereafter. On the basis of existing commitments, exports from developing countries should be about 0.4 billion boe in 1985 and 0.8 billion boe in 1990.

2.43 Most of the LNG projects that will add to supplies by 1985 are already committed or in the planning stage. Preliminary estimates derived

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1/ Countries are listed in Annex III. This estimate is based on a study undertaken for the Bank by BEICIP in 1980.

from a study undertaken by consultants for the Bank indicate that in the years to 1990 the total investments for LNG exports from developing countries might be of the order of US$32-56 billion (in 1980 dollars). Of this, about US$14-24 billion would be in exporting countries, for production, transmission and liquefaction plants, and the balance in the developed countri-- for LNG ocean carriers and terminals. Continuing negotiations over the future price of LNG, and the fact that the US Government has not yet decided on its LNG import policy, may delay the consideration of projects now pending. Some developing countries may be able to enter into export agreements for gas over and above what is currently projected or committed. But gas export contracts have a long gestation period, and LNG projects which are not yet in the planning stage are unlikely to be operational by the end of the decade.

2.44 According to the evidence gathered in Bank-assisted gas development projects, natural gas, and more particularly associated natural gas, remains one of the cheapest energy options in developing countries, particularly in those that have a large fuel oil market. Table 16 shows gas production costs (delivered to consuming plants) compared with the opportunity costs of fuel oil.

Table 16: SELECTED DEVELOPING COUNTRIES: COMPARATIVE COSTS OF NATURAL GAS PRODUCTION

	US Dollars per Barrel of Oil Equivalent	Opportunity Cost of Alternative Fuel at Appraisal Time (US dollars/barrel)
Associated Gas (Offshore) Delivered to Power Station (Egypt)	6.0	Fuel oil 19.5
Nonassociated Gas Offshore Delivered to Power Station (Thailand) /a	12.3	Fuel oil 15.4
Nonassociated Gas Onshore Delivered to Power Plant and Fertilizer Plant (Bangladesh)	4.0	Fuel oil 21.8
Nonassociated Gas Delivered to Residential Consumers (Egypt)	17.0	LPG 48.0

/a Gas produced by an oil company; includes return on equity.

Source: World Bank appraisal reports.

2.45 Few of the developing countries with proven gas reserves have developed a gas industry for the domestic market, primarily because the market has been too small to justify the large investment required in pipelines and distribution systems and partly because gas could not compete with petroleum products produced domestically or imported. While the production costs of nonassociated gas are on average comparable to oil production costs, 1/ transport by pipeline is on average five to eight times more expensive for gas than for oil of a thermal equivalence. In those developing countries that are exploiting their natural gas resources -- Algeria, Argentina, Bangladesh, Colombia, Mexico, Pakistan and Romania -- gas is mainly used for power generation and industry, which can absorb a large enough volume of gas to justify the construction of a pipeline. At current oil prices, gas can compete with oil provided adequate financing can be secured to finance infrastructure. This is an area where official aid could be particularly effective. Bank-assisted projects in Bangladesh, Egypt, Thailand and Tunisia include the financing of gas infrastructure.

2.46 The power sector will remain an important market in the early years of gas development in developing countries. Subsequently, when higher value uses for gas have been developed in the industrial, residential and possibly the transport sectors, power plants based on gas could be phased out or converted to use liquid fuels. Their conversion for the use of other fuels, particularly coal, is less likely to be economic in view of the heavy investments in boiler conversion, handling and storage facilities that would be required. This question is examined below in the section on electric power.

2.47 The BEICIP survey of natural gas potential in developing countries, referred to earlier, indicates that by 1990 natural gas could contribute about 1.4 million barrels of oil equivalent, or about 10-12 percent of their 1990 total commercial energy consumption. 2/ Of this total, about 500 million boe would be used for power generation; 700 million for industry (including fertilizers and petrochemicals); and 200 million for residential and commercial uses. As Table 17 shows, the total investments required would be about US$50-55 billion (in 1980 prices). This would correspond to an average development cost of about US$13,000 per daily barrel of oil equivalent.

1/ Production costs of associated gas depend largely on the location of the field (e.g. offshore or onshore) and the characteristics of production.

2/ Of this, 6-700,000 barrels a day of oil equivalent would be accounted for by gas production in China.

Table 17: DEVELOPING COUNTRIES WITH NATURAL GAS POTENTIAL: ESTIMATED INVESTMENTS FOR NATURAL GAS DEVELOPMENT FOR DOMESTIC USE, 1980-90
(Billion 1980 US dollars)

	Africa	Asia /a	Latin America	Total
Production	8.1	9.9	3.1	21.1
Associated Gas Treatment	5.1	7.0	8.0	20.1
Transmission	3.8	7.2	5.0	16.0
Distribution	1.3	4.7	4.8	10.8
Subtotal	18.3	28.8	20.9	68.0
Less Export-Oriented Production/Associated Gas Expenditures	6.8	6.1	1.4	14.3
Total	11.5	22.7	19.5	53.7

/a Includes China, with about one-third of the domestically-oriented investments.

Source: BEICIP, 1980.

2.48 To sum up, the relatively low level of natural gas use in the developing countries is the result of historical developments and of the limited interest of international oil companies in developing a source of energy that is not easily exportable. However, the economic context has changed, and these countries should make efforts to assess their natural gas potential and to develop it where feasible. Particular attention should be given to the residential sector where gas could be substituted for kerosene.

C. Coal 1/

2.49 In 1950, coal was the world's most important source of energy, accounting for 59 percent of primary energy production, while oil provided only 30 percent. By 1973 coal's share of world energy supplies had fallen to 29 percent, whereas oil's share had increased to 51 percent. Nearly 60 percent of the oil produced was traded, mostly from the Middle East to Europe, the United States and Japan, whereas only 8 percent of world coal production

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1/ For a fuller discussion of coal, including lignite and peat, see Coal Development Potential and Prospects in the Developing Countries (Washington, D.C.: World Bank, October 1979).

was traded, of which three-quarters was coking coal. Since the increase in the price of oil starting in 1973, coal has again become attractive, since it is plentiful worldwide, the technology of mining, moving and using it is well established, and it can be widely used in electricity generation and many industrial applications. However, long lead times are needed to establish new coal mines, related transport facilities, and coal-fired power plants.

2.50 The world's technically and economically recoverable reserves of coal are estimated at 636 billion metric tons of coal equivalent (3,095 billion barrels of oil equivalent) 1/ or about 5 times the proven reserves of oil. (Annex I Table 4 gives a breakdown of coal resources and reserves by country.) Total known coal resources are estimated to be nearly sixteen times larger than reserves. Although the developed market and centrally planned economies account for about 90 percent of presently recoverable reserves, coal resources in developing countries are widespread; comprehensive geological surveys and coal exploration programs in these countries would probably increase their coal reserves several fold. 2/ World thermal coal trade is presently very small, but it is likely to grow to 300-700 million tons of coal equivalent annually, equivalent to 200-470 million tons of oil, by the year 2000. Most of this trade will be among the industrialized countries, but there will also be export opportunities for developing countries.

2.51 World market prices for thermal coal are now US$30-36 per tce, equivalent to US$6-8 per barrel of oil. 3/ Depending on coal quality, transport requirements and environmental protection measures, coal may be up to 40 percent cheaper than oil for new power generating or industrial plants at the point of use.

2.52 Though coal production costs are not likely to rise much in real terms in the decade to come, the rising costs of competitive fuels and the pressure of future demand are likely to push coal prices up. The price of

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1/ Coal varies more widely in quality than other fuel minerals. The two most widely used classifications of coal are by calorific value and ultimate economic use. In the first classification, hard coal is distinguished from brown coal, which has less heating value. The second classification distinguishes between thermal coal for electric power generation, industrial and residential/commercial heating uses, and metallurgical or coking coals, used primarily as reductants in steel making. To treat the various types on the same basis, raw coal tonnages are normally converted into "tons of coal equivalent", each with a calorific value of 7,000 kcal/kg. Coal reserves are defined as coal occurrences which are exploitable under current economic and technical conditions. Coal resources are defined as coal occurrences which may acquire some economic value in the future.

2/ China is included here with centrally planned economies.

3/ Based on various issues of Coal Week and Coal International.

thermal coal delivered to users is expected to increase at approximately the same rate as world oil prices, but a more rapid increase in the second half of the 1980s is possible if international demand for coal gathers momentum. This would further strengthen the incentive to increase production. While most of the environmental problems associated with producing coal can be dealt with at a cost, the effects on the environment of carbon dioxide and sulfur emissions from coal-fired burners are a matter of considerable controversy among scientists, and further research on this important aspect is urgently needed.

2.53 A recent study has suggested that coal will have to provide one-half to two-thirds of the additional fuel needed by the world during the next 20 years. 1/ This would require more than a doubling of world coal production and an increase of as much as ten to fifteen times in world thermal coal trade by the year 2000. Such growth would require a worldwide investment of about US$150-300 billion for coal mines and associated transport facilities, and another US$25-50 billion for ports and ships for international coal trade (in 1980 dollars). If the increased coal production is to materialize, an early commitment by governments and the principal consumers to use more coal is needed.

2.54 From 1973-78, coal production in developing countries increased from 130 million tce to 162 million tce (or 5.7 percent of the world total) -- an average increase of 4.5 percent a year. Twenty-nine developing countries produce coal, but almost all of the production increase during that period came from only 9 large producers which provided 90 percent of LDC coal production in 1978, namely Brazil, Colombia, India, Republic of Korea, Mexico, Romania, Turkey, Viet Nam and Yugoslavia. Even in these countries, coal expansion has not been rapid and progress has been hampered in some cases by operating difficulties in existing mines.

2.55 Since 1974, coal exploration and preinvestment work has been undertaken in almost all developing coal producing countries, and coal mines are being developed in sixteen of them. These will provide an estimated annual production of 25 million tce (118 million barrels of oil equivalent) in the second half of the 1980s. Another 28 developing countries are known to have coal deposits, but produce no coal at present. Coal exploration and preinvestment work has taken place in only ten of them since 1974. In most of the other 18 developing countries 2/ there has been little systematic evaluation of geological information to identify coal occurrences or potential coal-bearing regions; basic exploration work is required to establish an inventory of commercial coal prospects.

1/ World Coal Study: Coal - Bridge to the Future (Boston: Massachusetts Institute of Technology Press, 1980). The Bank's preliminary estimates (Table 6) show coal providing about 30 percent of the increase by 1990, so that the relative importance of coal is likely to increase substantially in the 1990s.

2/ Benin, Bolivia, Cambodia, Cameroon, Costa Rica, Dominican Republic, Ecuador, Ethiopia, Guatemala, Guyana, Honduras, Jamaica, Lao PDR, Panama, Sierra Leone, Somalia, Trinidad, Tunisia.

2.56 With the present level of effort, coal production in developing countries is expected to reach 280 million tons by 1990, growing at an annual rate of about 4.3 percent during the decade. If a concerted effort were made to increase production as rapidly as possible, developing countries' production could nearly double, from 184 million tce in 1980 to about 348 million tons in 1990, a growth rate of 6-7 percent a year.

Table 18: DEVELOPING COUNTRIES: PROJECTIONS OF COAL SUPPLY AND DEMAND, 1980-90
(Million metric tons)

	1980	1985	1990	Average Annual Percentage Growth 1980-90
Coal Production	184.0	242.0	348.0	6.6
Coal Exports	1.2	8.0	35.0	40.1
(to other LDCs)	(0.8)	(3.0)	(11.0)	(29.9)
Coal Imports	10.0	20.0	32.0	12.3
LDC Coal Consumption	192.8	254.0	345.0	6.0

Source: Bank staff estimates.

Most of this growth is likely to be in countries that are already large producers of coal. But Botswana, Indonesia, Swaziland, Thailand and Venezuela could also be producing over 5 million tons each by 1990; Egypt, Haiti, Madagascar, Niger and Tanzania, which do not now produce coal, could become small producers, averaging 600,000 tons a year by 1990.

2.57 Although there are likely to be a few large coal export projects in developing countries during the next 10-15 years, most of the coal development will be for domestic consumption. In many developing countries with coal deposits substantial economic benefits could be obtained from small-scale coal ventures producing 250,000-400,000 tons a year. Possibilities for these should be actively explored.

2.58 New coal mines in developing countries require investments per ton of annual capacity of US$50-100 (in 1980 dollars) for coal mine development and US$50-100 for associated infrastructure, including transport facilities. 1/ Thus, a near doubling of LDC coal production from 1980-1990 could require

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1/ This is equivalent to an investment cost of US$7,000-15,200 per barrel a day of oil equivalent, including infrastructure.

an investment of about US$25 billion in 1980 dollars for both mines and infrastructure, including about US$2 billion which must be invested in exploration and preinvestment work during this period to provide the basis for new projects in the 1990s.

2.59 Over 50 developing countries consume coal, but only 15 consume more than one million tons a year. About 40 percent of LDC thermal coal consumption is used to generate electric power in 16 countries. By 1990 another ten developing countries will probably be using coal to generate electricity. Another 40 percent of the developing countries' thermal coal consumption is in industry, mostly in large plants such as cement kilns, pulp and paper plants and textile mills. Coal is particularly suitable for use in cement plants, and many countries are converting oil-fired cement plants to use coal. Many other industrial plants are now being designed with dual-firing capacity. About 20 percent of LDC thermal coal consumption is used directly by households. A few countries with well established coal industries (India, Republic of Korea and Turkey) use coal in households in one or more major cities. For many countries the investment costs of mining and distributing coal solely for household use may outweigh the benefits. But where industrial uses provide the main economic justification for developing coal, the large potential benefits from increasing its supply to the household sector -- particularly as a substitute for traditional fuels -- deserve attention. Over the coming decade, coal will become increasingly important in a number of developing countries, as feedstock for chemical products and synthetic fuels.

2.60 More rapid development of coal resources in developing countries will require large amounts of human, technical and financial resources. Coal can be a cost-effective alternative to imported fuel oil, as well as freeing oil and gas resources for export. Normally, the economic returns obtained from oil and gas projects are appreciably higher than those from coal developments, but the priorities for energy investment in individual countries must also reflect the composition of energy demand. For example, coal is most effectively used for power generation, whereas oil is better used for transport.

D. Synthetic Fuels

2.61 Raw materials such as coal or natural gas, which are themselves fuels, can be converted into synthetic fuels or feedstocks that are in greater demand and/or have greater values, or which can be more easily transported to domestic or export markets. At present the principal conversions envisaged are for the production of automotive fuels from coal and natural gas. The products obtained by processing the very heavy crude oil extracted from tar sands are also referred to as "synfuels" although the processes used are similar to those employed to convert residual fuel oil to light petroleum products in a refinery.

Coal Gasification and Liquefaction

2.62 Coal can be processed to produce either coal gas or liquid fuels. The gasification of coal nowadays generally involves partial combustion of the carbon in the presence of steam to produce a gas. If air is used, a gas of low calorific value is produced; using oxygen yields a gas with a higher calorific value. To obtain gas comparable to and compatible with natural gas, further processing is required. With increasing petroleum prices there is a renewed interest in the production of coal gas for direct use or for further conversion. There are two major drawbacks in the existing technologies: first, the small capacity of gasifiers, which makes it necessary to use several gasifiers simultaneously, and, second, low gasifier pressures, which mean that gas must be compressed before it is processed further. Experimentation with new techniques is unlikely to yield improved processes for industrial application before 1985.

2.63 Medium BTU gas from coal is adequate for domestic heating and can be used without further conversion. Medium BTU gas can also be converted to synthetic natural gas (SNG) by two additional steps which are both commercially well proven; it can also be used as a substitute for petroleum-based feedstocks in producing ammonia, but coal-based ammonia plants are more capital intensive than plants based on natural gas, as well as having higher energy requirements per ton of ammonia produced. Medium BTU gas produced by conventional gasification processes is suitable for industrial applications such as the direct reduction of iron ore for mini-steel mills.

2.64 Coal can be used to make methanol; while at this time no coal-based methanol plants are in commercial operation, several installations are planned in industrialized countries. Coal can also be used to produce liquid hydrocarbon fuels such as gasoline and diesel oil. Gasoline and diesel fuel are synthesized from coal at present only in South Africa. The technology is based on the Fischer-Tropsch process developed in Germany and used extensively in Europe during the Second World War. Byproducts include ammonia, fuel gas, solvents, and resins. The liquid fuel output cost is estimated to be in the range of US$40-60 per barrel of finished product. The lead time for planning and construction of such a complex is about 5 to 7 years, so that developing countries are unlikely to produce a significant volume of synthetic liquid fuels from coal before 1990. Coal-based fertilizer plants are likely to be economical in countries with low-cost domestic coal, limited or no natural gas resources and a large domestic fertilizer market, provided investment and operating costs can be minimized.

2.65 In many countries it is possible to make synthetic fuels from coal at production costs comparable to the retail prices of corresponding petroleum-based fuels. However, many of the technologies for so doing are complex and risky, the capital cost of plant is high, and the lead times for plant design and construction are long. Coal-based synthetic fuels are therefore unlikely to make a significant contribution to the energy needs of most developing countries in the coming decade. In the more advanced developing countries such as Brazil, India, Turkey and Yugoslavia, which are poor in petroleum but have large coal resources, pilot plants for producing liquid synthetic fuel may be built before 1990, and commercial synthetic gas plants are likely to be built to supply industry near the coal fields.

Methanol

2.66 The production of methanol from natural gas is emerging as an increasingly attractive way to meet domestic energy and feedstock requirements, and gas so converted can be exported over long distances. Before the development in 1926 of a synthetic technology to produce methanol, commercial quantities of methanol were produced from wood or other biomass (see Section E below). Methanol can now be produced from naphtha, residual oil and natural gas; these raw materials are first processed to produce synthesis gas (carbon monoxide and hydrogen) which in turn is treated catalytically by various methods to produce methanol. At present, most synthesis gas comes from steam reforming of natural gas, in plants whose capacity varies between 100,000 and 800,000 tons a year. This technology is well proven. The production cost of methanol varies widely with the price of the natural gas feedstock and the size of the production plant; the present range is US$95-170 per ton, equivalent to US$25-45 per barrel of oil equivalent. The standard methanol plant that would be economically viable on the international market would produce about 300,000 tons a year (or about 3,600 boe/day), which would require an investment of about US$140 million (in 1980 dollars), or about US$39,000 per boe/day capacity.

2.67 Historically, methanol has been used mainly as a chemical intermediate. Of the estimated 1980 world consumption of about 11-12 million tons of methanol, about 50 percent is expected to be used to produce formaldehyde. World demand for methanol is currently expected to grow at an annual rate of 6.2 percent between 1977 and 1990. However, several potential new uses of methanol suggest that this forecast may be conservative.

2.68 Potentially one of the largest new uses of methanol is the conversion of methanol to gasoline. The New Zealand Government has decided to construct a 12,500 barrel per day plant at an estimated cost of US$500-650 million; the estimated cost of the gasoline is believed to be in the range of US$50-60 per barrel. 1/ Other important new applications of methanol are as a chemical feedstock, an octane improver for gasoline (MTBE), a kerosene or diesel oil extender, a feedstock for the production of single cell protein (SCP), and a utility fuel to meet peak power needs.

2.69 A number of developing countries have natural gas deposits which are either too small to permit exports of LNG or for which the present or foreseeable domestic demand is inadequate to justify their full exploitation. Surplus natural gas could potentially be converted to methanol for export and perhaps used in the longer term as a feedstock for gasoline, SCP and chemical production.

1/ At a crude oil price of US$30/barrel, the ex-refinery value of gasoline is about US$43.50/barrel. See Annex II.

E. Renewable Energy Resources

2.70 Renewable energy resources fall into three broad categories: a) biomass in its traditional solid forms (wood and agricultural residues); b) biomass in nontraditional form (converted into liquid and gaseous fuels); and c) solar, wind and mini-hydro installations. 1/

2.71 Many developing countries depend heavily on traditional sources of energy, most of which are renewable, such as firewood, charcoal, crop residues and animal dung. In poorer countries these sources supply one-half to three quarters of the total energy used; the proportion varies from 50-65 percent in Asia to 70-90 percent in Africa. Such sources are particularly important in rural areas and among the urban poor, even in middle income countries. Overall they may account for the equivalent of 8.5 million barrels of oil a day, or roughly 20-25 percent of the energy consumed in the developing world, including China. 2/ In rural areas and among the urban poor, most of the energy is used for cooking. An estimated 2,250 million people in developing countries presently use traditional fuels for cooking.

The Fuelwood Crisis

2.72 The demand for fuelwood, the most important source of traditional energy for residential uses, including cooking, has grown far faster than supply. Whereas villagers once could usually find enough fuelwood near their homes, many now must search for it half a day's walk or more away, and the urban poor must spend large portions of their incomes on fuel. Many developing countries are therefore facing a second energy crisis which affects particularly the rural sectors of their economies. The magnitude of this fuel crisis is immense. As one of its dimensions, the forests of developing countries are being consumed at a rate of some 1.3 percent or 10-15 million hectares a year. Deforestation is most serious in semi-arid and mountainous areas where it causes serious problems of erosion, siltation and desertification. As fuelwood supplies are exhausted, animal and crop residues are burned, depriving the soils of valuable nutrients and organic conditioning material. The amount of dung now being burned annually is believed to be equivalent to some 2 million tons of nitrogen and phosphorous. A second dimension is that, if all developing country households now using traditional fuels were to switch to kerosene, developing countries' demand for oil would rise by 15 to 20 percent.

2.73 Although the fuelwood crisis has already reached serious proportions, technically and economically sound means exist both for reforestation and for improving the efficiency with which wood and other fuels are burned. On the

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1/ Large hydropower installations are also a form of renewable energy, but are discussed in Section F below, on electric power.

2/ Replacement by petroleum, however, would require only about 3 mbdoe because kerosene and gasoline stoves are more efficient.

order of 50 million hectares of fuelwood would need to be planted in the developing countries by the year 2000 to satisfy the projected demand for domestic cooking and heating. 1/ This would necessitate a five-fold increase over current planting worldwide. The gap between present and required planting levels is large in all regions, but particularly so in Africa. Here it is estimated that planting would have to be increased as much as 15-fold to assure adequate fuelwood supplies. In Asia, which already has serious erosion problems, not only must total planting be increased, but special efforts must be made to combine increases in planting with measures to control erosion.

2.74 The use of fuelwood can be made more efficient through the design and dissemination of improved stoves. Various simple and inexpensive improved stoves have been developed but they have not yet been widely disseminated. What is needed is extension to convey the importance of fuel conservation, and the suitability and benefits of improved stoves, to low-income families. Funding to assist small-scale enterpreneurs to make the stoves is also needed, backed by a vigorous marketing campaign, and research and development to adapt existing designs to local preferences and reduce costs. Increased and more efficient production of charcoal from wood, as well as briquets, pellets, and chips of wood and of agricultural and processing-plant residues, can provide economically transportable fuel supplies for both urban and rural uses. These biomass materials can also provide economic sources of energy for nonhousehold purposes. Small wood burning power plants can play an important role in rural electrification in some areas, and residues from processing plants can provide low cost fuel for agroindustrial operations.

Liquid Fuel from Biomass

2.75 The conversion of biomass to liquid fuel also holds considerable promise for application and development in developing countries. 2/ The production of alcohol, particularly ethanol (ethyl alcohol), from certain types of biomass, is a commercially well established technology. Alcohol in the form of methanol (methyl alcohol) can also be produced from wood.

2.76 Using alcohol as fuel could help to reduce the consumption of petroleum products for transport. Ethanol is produced by fermentation and distillation of carbohydrate materials such as sugarcane, sugar beet, and molasses, of which only a few are so far in commercial use. It can be used to power vehicles either by itself or in a blend with at least 80 percent gasoline. The greater density and octane-boosting effect of ethanol in blends compensate for its lower energy content so that, within limits, ethanol can substitute for an equal volume of gasoline with only minor engine modifications. Methanol-gasoline blends are much more difficult to use as vehicle fuels, and do not hold promise for the near future.

1/ Yields vary with area and species and average about 10 cubic meters per hectare per year. Rates of maturation also vary but are usually less than ten years for fast-growing fuelwood species.

2/ For a detailed discussion, see "Alcohol Production from Biomass: Potential and Prospects in the Developing Countries," World Bank, Report No. 3021, June 1980.

2.77 The economics of alcohol production greatly depends on the cost of biomass materials, which varies depending upon land availability, agricultural productivity, labor costs and other factors. Capital costs may also vary a great deal. Though few large-scale plants have been designed and constructed, plants with a capacity of about 20 million liters/year, or about 350 barrels a day, cost between US$10-20 million and require about 5,000-6,000 hectares of sugarcane annually. The Bank study referred to above suggests that alcohol production may be economically justified at present in situations of two kinds: in countries such as Brazil which are able to produce large amounts of sugarcane (or other biomass) at low economic cost, and in countries such as Fiji, Mali and Sudan, where surplus molasses are available from existing sugar production in mills in remote areas or where sugar has a low value. 1/ Research and development is being done to improve the efficiency of production and reduce costs, but it is still too early to assess the prospects for significant breakthroughs. Techniques for producing ethanol from feedstocks such as cassava, wood or sorghum that smallholders can grow efficiently on marginal land would be especially welcome. These could help to lessen the potential land use conflict between food and fuel, broaden the scope for producing ethanol in the developing world, and enhance the employment benefits of producing energy domestically.

Gaseous Fuel from Biomass

2.78 Biogas, a mixture containing 55-65 percent methane, can be produced from the decomposition of animal, plant and human wastes. It can be used directly in cooking, reducing the demand for firewood. Moreover, the material from which biogas is produced retains its value as a fertilizer and can be returned to the soil. China and India have both launched large-scale biogas programs at various times and with varying levels of success. Whether family biogas units are an economic source of fuel depends on their cost relative to family income, and the economic cost of the dung to be used as raw material. Partial combustion of wood or other carbonaceous material such as straw, nutshells, coal, bark, or rice hulls, produces a gaseous mixture ("producer gas") with a low calorific value, which can be burned in boilers designed for liquid or gaseous fuels or filtered for use in internal combustion engines. Producer gas can be used as fuel in agroindustrial plants with substantial residual materials. The production and use of both biogas and producer gas could be viable much more widely in the rural areas, given funds for research and development, incentives for industrial experimentation and an effective extension mechanism.

1/ The key assumptions are that the economic cost of gasoline ex refinery is US$1 per gallon (equivalent to Gulf crude at about US$30 per barrel), rising at 2.5 percent a year in real terms, and that the rate of return on total investment is 10 percent. Plant construction costs are "medium" if the cost of sugarcane is below US$14 per ton and that of molasses is less than US$60 per ton. The present price of sugar is much higher, but by 1985 the price is projected to be US$14.

Direct Use of Sun, Wind and Water Power

2.79 Solar, windpower and mini-hydro technologies are a third source of renewable energy for developing countries. A firm technical basis exists for small hydro and windpower projects, and they appear to be economically attractive for suitable sites, but there has been little recent experience with them and much more exploration of sites is needed to assess their potential role. Water heating by flat plate collectors is the solar technology most ready — technically, economically and commercially -- for widespread application. Some developing countries have begun to manufacture their own solar water heaters, and many others could do so. Flat plate collectors can be an economical source of hot water for residences and industry; they can also provide heat for drying crops and for certain other agricultural uses.

2.80 Photovoltaic (PV) cells, which convert solar energy directly into electricity, appear technically well suited to many applications in developing countries because they promise to be long-lived and relatively trouble-free in operation. But while the cost of photovoltaic electricity is falling, it is still at levels (on the order of US$2/kWh) which make it commercially viable only where relatively small amounts of power are needed in remote locations (such as telecommunications repeater stations, navigational buoys and beacons). The use of photovoltaic cells to meet power needs on a large scale is being tested in a number of village electrification and irrigation projects (where diesel-generated power costs US¢ 20-45/kWh), notably in Saudi Arabia and Senegal. Some applications of this type are likely to become economical in favorable locations as the cost of photovoltaic electricity falls. The Bank is acting as Executing Agency for a UNDP project that is testing and demonstrating PV and solar-thermal powered small irrigation projects.

Potential and Problems of Renewable Energy

2.81 The developing world is, by and large, amply endowed with solar and biomass resources. These resources are particularly well suited to meeting the widespread need for small, decentralized sources of energy in rural areas where, owing to the lack or high cost of energy from conventional sources, renewables may prove economical sooner than in the industrialized countries. The pace at which the developing countries can exploit their renewable energy potential will be determined in good measure by their ability to create or strengthen institutions for this purpose. Progress can easily be hampered by the lack of a coherent national energy plan within which the role of renewable energy can be defined, priorities among the various technologies determined, and resources assigned -- especially when programs to develop renewable energy sources begin to require important policy and budgetary commitments. To use these resources on a wide scale will require extension and other delivery systems that are capable of reaching the urban and rural poor with technical and social assistance and credit facilities.

2.82 The third area of fundamental importance in renewable energy development is research and adaptation of techniques to local conditions. The developing world, by no means uniquely, finds itself short of the expertise needed to evaluate and exploit these resources. There are important gaps in the developing countries' ability to select from and adapt to their needs technologies being studied and developed by the industrialized countries, and especially technologies whose greatest potential is in the developing countries. To fill these gaps, attention needs to be given to strengthening national research programs and to the possibility of organizing international programs of research on specific renewable energy technologies.

F. Electric Power

2.83 A modern electric power system transfers electrical energy produced by a variety of sources (hydro, thermal, geothermal or nuclear) to industrial, commercial and domestic consumers in a large region to operate machines, equipment and appliances. It must be designed to meet varying levels of demand and to provide for demand growth. Particular sources of power have advantages for meeting different requirements: steam or nuclear power for base load; hydropower for mixed base load/peaking, depending on how much water is available; steam or combined-cycle units (combustion turbines plus steam) for the middle range; and combustion turbines or pumped storage (combined with nuclear power or base load thermal) for peaking. Particular power sources also have varying reserve requirements, which may range from 10 percent for a large hydro system to 100 percent for a small 2-unit diesel system. The ability of a power system to take advantage of the characteristics of different generating sources depends largely on its size. Some developing countries with large modern systems, such as the Republic of Korea, are now at the forefront of power system development. Countries with smaller systems, or which have to provide for villages that cannot yet be linked to the national grid, are more restricted in their choice of power sources, but they too should be constantly aware of the possibilities of increasing efficiency as their systems expand.

2.84 Comparative costs of power generation, derived from typical Bank projects, are shown in Table 19. With the doubling of oil prices in 1979, nuclear energy and coal have an even greater advantage over oil for producing electric power. At today's oil prices, generating capacity must be planned to use oil efficiently and to use alternative power sources where appropriate. In the past, steam plants fired by fossil fuels have usually operated at various places in the load curve over their useful life: when new they are often the most efficient plants in the system and hence are best used at the base; as newer, larger and more technically efficient plants are added, the older thermal plants are gradually displaced, until finally they may be used only for standby. It is clearly economical to use coal rather than oil-fired boilers for new steam plants if the system needs more base-load capacity, and assuming the country does not wish to or is unable (because the system is small) to install nuclear plants.

Table 19: OIL IMPORTING DEVELOPING COUNTRIES: COMPARATIVE COSTS OF POWER GENERATION BASED ON VARIOUS TYPES OF FUEL
(Delivered cost to major consumers)

Generator Type		Investment Cost /a US Dollars per kW Installed	Fuel Cost 1980 US¢/kWh	Power Cost 1980 US¢/kWh
Hydropower	- Large, High Head	1100	n.a.	2.4
	- Low Head Mini-Hydro	3500	n.a.	12.7
Diesel	- Large, Heavy Oil Fuel Coastal Location	1000	4.2	6.7
	- Small, Light Oil Fuel Inland Location	800	10.9	13.2
Steam	- Large, Gas-Fired	800	0.4	2.4
	- Large, Coal-Fired	1000	2.7	5.2
	- Large Oil (Imported) Fired	800	5.5	7.5
	- Small, Heavy Oil-Fired Inland Location	1400	7.3	11.4
	- Small, Wood-Fired	1500	3.0	10.0
Geothermal	- Dry Steamfield	1400	n.a.	3.0
	- Wet Steam/Hot Water Field	2800	n.a.	6.0
Nuclear	- Large Multiple Units	1600	1.0	5.1
	- Single Small Unit	2200	1.0	7.4
Solar Photovoltaic		20,000-30,000/b	n.a.	100-300
Wind Generator		5,000-15,000/b	n.a.	30-100

n.a. Not applicable.

/a Investment cost includes cost of transmission and distribution.

/b Both solar energy and wind power are intermittent energy sources which require storage to make energy available on demand at all times. Investment costs given above are system costs with storage included.

Source: World Bank staff estimates; see Annex II for the underlying assumptions.

2.85 Whether an existing oil-fired plant should be converted to burn coal is a much more complex issue, which requires a thorough analysis of the power system taking into account, among other things, the shape of the load curve, the number, sizes and types of existing plants and the likely sizes and types of future capacity. The choice also depends on such considerations as the space available for coal handling and storage, the facilities for transporting coal, and the willingness of the authorities to accept the greater environmental problems of coal over oil (or, alternatively, to install expensive equipment to remove sulfur and other pollutants). Assuming that these problems can be overcome or tolerated and that the plant will be operated at close to its capacity over most of its remaining life, conversion from oil to coal should be considered. At a low level of use, the saving in fuel costs would not recover the incremental cost of the conversion.

2.86 It is unlikely that conversion of existing plants to coal will take place on a large scale in the foreseeable future. In certain oil importing developing countries, however (Cyprus, Jamaica, Republic of Korea, Panama, Philippines, Portugal, Turkey, Uruguay), the substitution may be economical, on two conditions: a) that the costs of the necessary infrastructure (ports, railways) can be shared with other sectors of the economy, and b) that, in countries with refineries, the substitution of coal does not add to a surplus of residual fuel oil that is already difficult to dispose of economically. Studies to this end are underway in several of these countries.

2.87 The installed electricity generating capacity in the developing countries is expected to be 241 gigawatts (GW) or 12 percent of the world total by the end of 1980. Between 1973 and 1978, these countries' electricity consumption grew at an average rate of 8 percent a year, compared with 3.5 percent a year in the developed countries. Even so, their per capita consumption in 1978 was still only 331 kWh, compared with 6,509 kWh in the developed countries. A recent study by the Bank of about 90 countries with per capita incomes below US$2,200 estimates that their electricity consumption will grow at an annual rate of 8-9 percent in the next decade. Table 20 shows the development of expected generating capacity by source, and Table 21 the projected evolution of electric power production, also by source.

Table 20: DEVELOPING COUNTRIES: POWER GENERATING CAPACITY, 1980-90

	1980		1985		1990	
	Gigawatts	Percent	Gigawatts	Percent	Gigawatts	Percent
Thermal /a						
Oil	90.3	37.4	112.2	31.3	129.1	24.7
Gas	12.5	5.2	29.9	8.3	60.7	11.6
Coal/Lignite	35.1	14.5	58.2	16.2	92.2	17.6
Subtotal	137.9	57.1	200.3	55.8	282.0	53.9
Hydro	99.6	41.3	147.0	41.0	201.3	38.4
Nuclear	3.4	1.4	10.2	2.8	38.1	7.3
Geothermal	0.4	0.2	1.4	0.4	2.3	0.4
Total	241.3	100.0	358.9	100.0	523.7	100.0

/a Estimated fuel breakdown based on primary fuel (some stations are dual fueled).

Source: Bank staff estimates.

Thermal power will remain the dominant form during the 1980s although its share will decline; coal- and gas-fired generation will increase at the expense of oil-fired. Hydropower capacity is expected to double, although its share in total electricity production will drop slightly. Nuclear power, presently confined to a few developing countries, will increase its share of production substantially during the decade.

Table 21: ELECTRICITY PRODUCTION IN DEVELOPING COUNTRIES, 1980-90

	1980		1985		1990	
	Terawatt Hours	Percent	Terawatt Hours	Percent	Terawatt Hours	Percent
Thermal						
Oil	272	30.5	346	25.0	388	19.2
Gas	55	6.2	131	9.5	213	10.5
Coal/Lignite	154	17.2	255	18.4	404	20.0
Subtotal	481	53.9	732	52.9	1,005	49.7
Hydro	394	44.2	592	42.7	777	38.4
Nuclear	15	1.7	51	3.7	225	11.1
Geothermal	2	0.2	10	0.7	15	0.8
Total	892	100.0	1,385	100.0	2,022	100.0

Source: Bank staff estimates.

Primary Sources of Electricity

2.88 Hydropower. Roughly half of the world's hydropower potential is in the developing countries, totalling about 1,000 GW, of which only 10 percent has been developed (see Annex I, Table 5). Given the large increases in oil prices, many hydro sites which were previously uneconomical have become attractive. At fuel oil prices in the range of US$20-25 per barrel, hydropower costing US$2,500 to US$3,000 per kilowatt of installed capacity can be competitive with oil-fuelled steam units or large diesels, if there is sufficient water to operate at 50-55 percent of capacity. At this investment cost, hydroelectricity would cost about US7¢/kWh. About 100 GW of hydro capacity is projected to be added over the next decade in some 60 developing countries.

2.89 Mini-hydro projects, with capacity of under 1 MW, could potentially harness 5-10 percent of the world's total hydro resources. It is estimated that the economic limit for mini-hydro projects is in the US$2,000-3,000 per kilowatt range, depending on the thermal alternative and the type of power market; their relatively high investment costs may make mini-hydro projects uneconomical for village systems with low load factors. If they can be connected to the central grid, mini-hydro plants can be more effectively used when water is actually available, not only by providing additional capacity but also to replace energy supplied by fuel. In isolated areas, for village electrification schemes and small industry, they can also supplement or replace high speed diesels.

2.90 Geothermal Power. Geothermal energy is derived from the natural internal heat of the earth. It is extracted as a heated fluid, usually water or a mixture of steam and water, but sometimes dry steam. In Iceland, Italy, New Zealand and the United States, geothermal energy has been employed for space heating, hot water supply, process heat and electric power generation. Goethermal resources are geographically widely distributed. Very few of those in developing countries have so far been exploited, both because alternative sources of energy have been cheaper and because geothermal energy must be used for heating or converted to electric power at, or very close to, the place where it is tapped. At present prices for fuel oil, however, geothermal power generation is economically attractive in many countries. While its capital costs of US$1,000-2,400 per kilowatt, including production wells and gathering systems, are higher than those of conventional thermal development (US$400-1,200 per kilowatt), geothermal plants have no fuel requirements once the initial development phase has been completed.

2.91 The total geothermal capacity in developing countries is projected at 2,300 MW in 1990. The probable producers by then include El Salvador, Indonesia, Kenya, Mexico, Nicaragua and the Philippines. The Bank has recently financed geothermal projects in El Salvador and Kenya. In other countries believed to have geothermal potential, exploratory survey and drilling work should be undertaken in order to evaluate reserves and to estimate production potential and development costs. Shortages of personnel experienced in geothermal work are likely to be the main factor limiting the expansion of geothermal exploration and development.

2.92 Nuclear Power. In 1978, 7 percent of the world's electricity was supplied by nuclear power stations located mainly in Europe, Japan, North America and the USSR. Less than 2 percent of the electricity in the developing countries is presently supplied by nuclear energy. The installed nuclear capacity in the developing world in mid-1980 totals about 3.0 GW in Argentina, India, Republic of Korea and Pakistan. Mexico, Philippines, Romania and Yugoslavia have nuclear units under construction and by 1990 Egypt, Portugal, Thailand and Turkey may have nuclear units in service. During FY1981-85, the developing countries are expected to add about 6.8 GW of nuclear capacity to their systems, at a cost of about US$10 billion (US$1,500 per kilowatt); financing has been provided largely by supplier credits and bilateral agencies.

2.93 Reactor units need nominal rated capacities of 600 MW, 900 MW, and 1,300 MW to be commercial -- a fact which in the past has limited the number of countries that could use nuclear power in a balanced system. It is forecast that by 1990 a further 12 developing countries will have power systems of 5,000 MW or larger, permitting them to consider nuclear plants of the present minimum commercial size of 600 MW. Smaller units have been supplied in the past and are being reconsidered by manufacturers, but are not yet thought to be economical, especially when compared to coal-fired plants.

2.94 Although nuclear plants have not achieved the high utilization factor long claimed for them, they now seem to have a significant advantage for base load units. They do, however, require lead times of about 10 years. Nuclear plants raise a variety of safety and environmental issues including the possibility of loss of coolant, the hazards involved in transporting fuels, and the difficulties of processing, storing and disposing of radioactive wastes. Countries that will have large enough power systems by the turn of the decade should consider now whether they wish to include nuclear plants in their plans for the 1990s, usually as alternatives to coal-fired plants and in the context of current safety and political issues affecting nuclear energy.

Power Investment

2.95 A broad estimate of the total investment over the next decade (1981-90) for electric power facilities in the developing countries is given in Table 22. Of the total of US$14 billion (in 1980 prices), about 28 percent is for thermal, 28 percent for hydro, and 14 percent for nuclear and geothermal electricity. Transmission accounts for 10 percent and distribution for about 20 percent divided about equally between urban and rural systems.

Table 22: DEVELOPING COUNTRIES: ELECTRIC POWER INVESTMENT, 1981-90
(1980 prices)

	Unit Cost $/kW /a	1981-85		1986-90		1981-90	
		Giga-watts	Billion US Dollars	Giga-watts	Billion US Dollars	Giga-watts	Billion US Dollars
Thermal	1,160	62.4	72	81.7	95	144.1	167
Hydro	1,730	47.4	82	54.3	94	101.7	176
Nuclear	1,920	6.8	13	27.9	54	34.7	67
Geothermal	2,100	1.0	1	0.9	2	1.9	4
Total		117.6	169	164.8	245	282.1	414

/a Unit costs also include amounts for transmission and distribution facilities.

Source: Bank staff estimates.

These estimates are based on forecasts of additional capacity requirements identified in plans for power expansion that are now being implemented. The required investment is large and may pose serious difficulties for many developing countries.

Chapter III: THE DEMAND FOR ENERGY AND ITS MANAGEMENT

3.01 Developing countries consume a small share (12 percent) of the world's commercial energy. However, their economies are growing faster than those of the industrialized countries, and their demand for commercial energy, with the rapid growth of cities, industries, motorized transport and other energy-intensive developments, is increasing faster than GNP. In the past, much of the increased demand has been met by oil, and most developing countries must import all or a portion of their oil requirements. Table 23 shows the present and projected energy balances of developing countries, and Table 24 the oil imports of oil importing developing countries.

Table 23: DEVELOPING COUNTRIES: PRIMARY COMMERCIAL ENERGY BALANCES, 1980 AND 1990
(Million barrels a day of oil equivalent)

	1980				1990			
	LDCs		OIDCs		LDCs		OIDCs	
	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.
Oil	13.5	9.2	1.7	6.2	19.4	15.4	3.3 /a	10.9
Gas	3.0	1.5	0.9	0.8	5.2	3.0	1.2	1.2
Coal	2.5	2.6	2.2	2.2	3.7	3.8	3.1	3.1
Hydro	1.9	1.9	1.8	1.8	4.1	4.1	3.5	3.5
Nuclear	0.1	0.1	0.1	0.1	1.2	1.2	1.0	1.0
Other /b	(.)	1.4	(.)	(.)	1.9	3.1	1.2	0.8
Total	21.0	16.7	6.7	11.1	35.5	30.6	13.3	20.5

(.) Less than half the unit shown.

/a Production level projected in Case 1, as described in Chapter II. The production level in Case 2 is 4.5 million barrels a day of oil.

/b "Other" includes exports of gas, alcohol, other nonconventional primary energy sources and unallocated energy.

Sources: World Development Report, 1980 and Bank staff estimates.

Table 24: OIL IMPORTING DEVELOPING COUNTRIES: OIL IMPORTS, 1970-90

	1970	1975	1980	1985	1990 Case 1	1990 Case 2	Average Annual Percentage Growth 1970-80	Average Annual Percentage Growth 1980-90 /a
Net Imports /b (Million Barrels a Day)	1.8	4.4	4.5	6.0	7.6	6.4	9.6	5.4
Cost of Imports /c (Billion 1980 US Dollars)	5.4	31.5	49.3	76.6	111.0	93.4	24.8	8.5
Middle Income Countries	4.2	27.9	43.8	67.7	99.3	84.6	26.4	8.5
Low Income Countries	1.2	3.6	5.5	8.9	11.7	8.8	16.4	7.8

/a Growth rates for 1980-90 refer to Case 1.
/b Includes oil used as fuel as well as lubricants, feedstock for fertilizer and petrochemicals, and other industrial uses. Fuel use typically accounts for 90 percent of the total.
/c Average costs per barrel, 1970 and 1975, in 1980 dollars. 1980 price is US$30 per barrel, assumed to increase at 3 percent a year in real terms.

Source: Bank staff estimates.

3.02 The oil consumption of middle income oil importing countries is much larger than that of low income countries, and their imports are nearly ten times as large. In the decade to come, as the result of somewhat higher GNP growth rates, their imports are expected to grow somewhat more rapidly than those of low income oil importing countries, although the latter have more limited opportunities for substituting other sources of energy and for increasing oil production. The main oil producer among the low income countries is India, whose production is expected to level off in the mid-1980s unless there are additional discoveries.

3.03 The striking feature of the projections is that, though their oil production is expected to double by 1990 (Case 1) and their energy supplies from other sources will increase, the import expenditures of the oil importing developing countries in real terms are also expected to double. Their consumption of oil will continue to increase, although the annual growth rate is expected to decline from the 7.7 percent experienced in the 1970s to 5.8 percent in the 1980s, as the result of a slower growth in GNP and the effect of rising real prices.

3.04 These rates of oil consumption and import growth could be significantly reduced if both energy production and conservation measures were carried out to their full potential. With a maximum effort to exploit their ultimate recoverable reserves of oil (Case 2), oil importing developing countries could be producing an additional 1.2 million barrels a day by 1990, saving about US$18 billion worth of imports (in 1980 dollars) as compared with the continuation of present trends (Case 1). As suggested later in this Chapter, a major conservation effort could more than double these savings, and additional production of other energy sources could increase them further. Even these massive efforts would still leave the oil importing developing countries with a larger real import bill in 1990 than they have now. But the effects on GNP and the claim of oil imports on export earnings could be very important. The import expenditures in Case 1 rise from 3.3 percent of GNP in 1980 to 4.5 percent in 1990, and from 25 percent to 32 percent of projected export earnings. But those in Case 2, coupled with an energetic program of demand management, would leave import and export earnings in 1990 at roughly the same percentages of GNP as in 1980.

3.04 Improving the efficiency of energy use means using each source of energy in such a way as to increase the value of energy output from a given volume of resources, and reducing waste in each energy using activity. Even where, as in most developing countries, per capita consumption of energy is small, demand management policies can shift consumption from lower to higher value uses, reduce the energy cost of output and promote a switch from more to less costly sources of supply. At the national level this means setting priorities among the principal uses of energy--for example, industrial versus commercial or household activities, public versus private transport, energy-intensive versus non-intensive activities--and ensuring that government policies generally are consistent with these priorities.

3.05 An essential tool in most countries, developing and industrialized, for increasing energy efficiency is a pricing policy which ensures that, as far as possible, the price of energy in various uses reflects its real economic cost. For most energy products this means the highest price for which they could be traded either within the country or with other countries. It is only when the product cannot be traded, or cannot substitute for another energy product which is traded, that its economic price is its cost of production or replacement. In many cases, the achievement of economic pricing of energy products requires either the removal of inappropriate government-imposed pricing restrictions or adjustments in government policies.

3.06 A government can tax some or all energy products to encourage energy conservation or interfuel substitution. Where political and strategic factors suggest that there may be uncertainties in obtaining energy products from abroad, a government may also allow a premium over economic prices in assessing the viability of developing indigenous energy resources. Governments can also use a variety of nonprice controls, such as import restrictions, quantity rationing or quotas, for selective short-term intervention in the market for certain energy and energy-related products, while fundamental price adjustments are being made. Finally, it may be necessary to impose on government agencies, which are often insensitive to--or insulated from--market forces, various forms of budgeting or rationing to ensure that the energy consumed in public projects and services also reflects its real cost. Administrative and pricing policies need to be backed by education programs for the general public and for particular kinds of energy consumer, to help overcome political resistance to realistic prices for energy and to inform them of available technologies. Training in good energy practices should be encouraged for all who operate equipment that produces or consumes energy.

3.07 In most countries the distribution of energy among the principal uses has been influenced by subsidies, price controls and other forms of regulation to ensure low prices for particular uses or types of consumer; low tariffs for electric power, designed to foster industrialization, are a familiar example. The objection to such policies by the Bank and others in the past was less that they led to rapid and wasteful growth in the use of energy than that the underpricing prevented energy suppliers from earning sufficient revenues to finance future investment, while augmenting the need for more capacity. The concern, that is to say, was more with the economical use of capital than that of energy. But now that energy is no longer cheap or abundant, energy efficiency must be considered as a principal element in economic planning, and energy demand management must take its place with other forms of economic management. At the present and prospective prices of oil, and the cost of producing alternatives, energy like capital is an expensive commodity whose use requires careful attention.

3.08 Policies and practices evolved when energy was cheap will not be changed overnight. There is resistance in all countries to the removal of controls that hold down fuel prices or to measures that divert energy away from consumers who have been accustomed to ample supplies in favor of more economically desirable uses. But significant improvements can be made quickly, and more fundamental ones need to be planned for. These are complex matters, and few governments have at their disposal either the essential information or the technical and administrative skills to manage energy demand effectively.

3.09 The energy situation varies widely among countries and there is no universal prescription for a program of demand management. In the poorer developing countries most of the commercial energy is used by the more affluent city dwellers, and in industrial and transport activities related to their needs. Consumption patterns in these areas, and in the middle income countries, resemble those in high income countries. Studies carried out in urban areas of developing countries indicate that the top 20 percent of income recipients use 60 percent of the commercial energy consumed by households, against only 15 percent by the poorest quintile, owing to their greater use of modern appliances. In rural areas and among the urban poor kerosene is used not only for cooking but also for lighting. The majority of the rural population relies largely on wood for cooking, usually on open fires or in stoves that make effective use of only a small fraction of the wood's heat.

3.10 The following sections discuss measures for energy demand management in agriculture and the main energy using sectors--private households, transport, industry and electric power. While particular measures must be fitted to particular circumstances, the approach discussed below will, in varying degrees, be relevant in formulating demand management policies.

A. Agriculture

3.11 Agricultural production typically accounts for less than 5 percent of a country's commercial energy consumption. It follows that management of demand in agriculture is unlikely to lead to a substantial reduction in a country's total energy use. Nevertheless, rising prices for petroleum-based energy will adversely affect the costs of production and the rate of technological innovations that depend on combinations of improved varieties, assured irrigation and the application of petroleum-based chemicals such as fertilizer and herbicides.

3.12 Higher energy prices will have least effect on subsistence agriculture, and most on agricultural systems beginning to use yield-increasing technologies, especially fertilizers; in many rice producing systems, purchases of fertilizers comprise as much as half of cash outlays. However, at expected price ratios fertilizer will continue to be profitable provided it is used efficiently. Higher energy prices will also raise the costs of tubewells and other forms of irrigation that depend on pumpsets driven by diesel fuel, although in some circumstances the availability of fuel may be more important than its price. Finally, the increase in energy prices is bound to increase the total costs of mechanization.

3.13 There is no readily identifiable yield-increasing technology other than the improved seed-water-fertilizer approach that has characterized the Green Revolution of recent years. It is an essential part of agricultural strategy in areas, such as most of Asia, where land is scarce. In the next two decades it is expected that close to three-quarters of all increases in output of basic staples will have to come from yield increases; in the past decade yield increases have only supplied half of the increase in output. Consequently, energy demand will have to be carefully managed so as to sustain technological change in a situation where the real costs of inputs to produce basic foodstuffs are likely to rise more rapidly than the prices of those products.

3.14 First, economic policies that encourage wasteful uses of energy, such as subsidies on high-cost mechanization, or pricing systems that encourage pump irrigation relative to gravity irrigation, should be changed. The second and possibly more significant approach is to make better use of energy by improving farm practices. It is estimated that only 30 percent of the plant nutrient in chemical fertilizers applied in developing countries is used by the plants and the rest is wasted; vast quantities of water, some of it pumped by oil-fuelled pump sets, are also wasted. In rice production, root zone placement of fertilizers can be up to 50 percent more efficient than traditional broadcast methods. In many of the developing countries the scope for increasing the efficiency of inputs is so great that, for some time at any rate, further production increases are feasible with present technologies provided there is vigorous expansion of extension services, backed by applied research.

3.15 More research needs to be done on such new approaches as biological nitrogen fixation and solar pumps for irrigation. There is also significant scope, particularly for small farm use, for developing crop and farm technologies that use crop residues and organic byproducts as partial substitutes for chemical fertilizer. Several of these possibilities are being addressed in Bank-financed research and extension projects and in the development of better water management practices under irrigation projects.

3.16 Higher energy costs affect agricultural marketing and processing. As the fraction of the population living off the farm continues to increase, there will be an increasing demand for energy to move food and fiber from the producer to the domestic consumer. Moreover, the increase in international transport costs associated with rising energy costs will lend added importance to domestic production and processing for local markets. These issues are considered below in the discussion of the transport and industrial sectors.

Competition Between Food and Energy Crops

3.17 The possibility of large-scale production of energy from biomass (see Chapter II) poses the question whether, and to what extent, such a development is likely to compete with food for land and other agricultural resources. If energy prices continue to rise faster than agricultural prices, the potential competition for land between food, export and energy crops will be heightened as economic forces increasingly draw agricultural resources into energy production. Whether to produce energy from biomass will often require difficult choices which cannot be resolved using strict economic criteria. This is particularly true when such production affects the incomes of large numbers of poor people. For example, if a biomass energy program to produce substitutes for gasoline reduces the production of basic foods and raises their prices, poor urban consumers may suffer even though other groups in the economy may benefit from the new cheaper fuels.

3.18 A few developing countries have abundant agricultural resources and can bring new lands into production at reasonable cost. In other countries, possible ways of reducing competition between energy cropping and production of food and other agricultural commodities include:

- Increasing yields per hectare of the traditional energy crops, by research and extension work, thereby reducing their claim on land.

- Planting energy crops other than sugarcane. Sweet sorghum, for example, may yield 50 percent more alcohol per hectare than sugarcane.

- Producing raw materials on lands that are marginal for agriculture. Cassava will generally grow on lands unable to sustain food or other annual crop production, but cassava yields need to be increased. Forest products could become important sources of ethanol (and methanol) if cellulose conversion technology can be improved; the area of marginal land under timber greatly exceeds the land available for sustained agricultural biomass production.

B. Household Use of Energy

3.19 Households account for an average of about 45 percent of the developing countries' total energy consumption, but only 10-20 percent of their commercial energy consumption. In low income countries, these shares are 75 percent and 10 percent respectively, and in middle income countries, they are 20-40 percent and 10-20 percent respectively. Much of the noncommercial energy consumed by households has limited marketability. Households in developing countries use energy mainly for cooking. Space heating and cooling become significant only at the upper income levels, except in countries such as the Republic of Korea and Turkey which have severe winters. In the United States, by contrast, the heating and cooling of residential buildings alone accounts for 22.5 percent of total energy consumption.

3.20 Firewood, charcoal, crop residues and animal dung account for virtually all of the energy used in many rural areas and for about 25 percent of total energy consumption in developing countries. Africa is most dependent, Asia somewhat less, and Latin America least dependent on such sources. Some 2 billion people, or about 75 percent of the population of the developing countries, presently use traditional fuels for cooking. Most of these people have access to firewood, but between 0.5 and 1 billion use agricultural and animal wastes to fuel their cooking fires. As noted in Chapter II, developing countries have been consuming their wood supplies far more rapidly than they can be renewed, with grave environmental, social and economic consequences.

3.21 Controls over the cutting of wood, or the delivery of wood and charcoal to towns, are likely to be ineffectual, and promoting a shift to commercial fuels by price subsidies obviously has severe limits when the population of towns is growing as rapidly as it is. Designing and promoting the use of more efficient stoves would help considerably, as would the exploitation of agricultural wastes to provide liquid or gaseous fuels and other renewable energy devices along the lines discussed in Chapter II. Specific measures to address the energy needs of rural households need to be conceived as part of a rural development strategy that includes reforestation and the planting of trees on marginal land in cultivated areas.

3.22 The availability of traditional fuels in most developing countries complicates the problem of charging cost-based prices for commercial fuels. In many developing countries townspeople use wood or charcoal for cooking, and in the countryside these fuels may appear to be a free good. Thus, raising the price of commercial fuels to limit the growth of demand for them will make traditional fuels more attractive, adding to the pressures on forests. Moreover, the poverty of both rural and urban households has persuaded governments to subsidize kerosene and provide "life-line" rate electricity tariffs to ensure a minimum supply for poor people at a price they can afford. On environmental and social grounds there may therefore be a case for charging less than economic prices for commercial fuels and power. The difficulty is to confine these benefits to consumers who really need them. Subsidized kerosene can be, and frequently is, used to adulterate gasoline and diesel fuel for vehicles. Low electricity tariffs can benefit better-off households as well as the poor. To avoid perverse effects of this kind, subsidies and price controls should be used only to the extent that they are clearly needed to further social and environmental objectives. Efforts also need to be made to collect information on the use of commercial and traditional fuels by households, so that the effect of changes in energy pricing can be observed.

C. Transport

3.23 Transport accounts for 15-25 percent of total direct energy use in industrial countries, and for a similar or slightly higher proportion in middle income developing countries. 1/ In many low income countries, by contrast, this sector accounts for only 10-20 percent of total energy consumption. Road transport (cars, trucks and buses) which accounts for 70-85 percent of the energy directly consumed in the transport sector, is by far the largest consumer; rail and air transport typically consume about 3-5 percent and 5-10 percent respectively. Except in a few countries where railways are still fuelled by coal or are electrified, mainly on the basis of hydropower, the transport sector depends almost entirely on petroleum, and in many countries uses more than half the total petroleum products consumed. Some countries, notably Brazil, have begun to use alcohol fuels produced from grains as motor fuel substitutes. Others, such as the Republic of Korea, are experimenting with LPG-powered vehicles. Extensive research is being carried out in developed countries into electrically powered vehicles. It is possible that the 1980s may see the development of viable vehicles powered by gasohol, LNG or LPG, which may later may be displaced by electrically powered vehicles. For the foreseeable future, however, gasoline, jet fuel and diesel oil derived from petroleum or synfuels are likely to continue to be the major energy sourcesof the transport sector. Attempts to improve energy efficiency in the sector are therefore particularly desirable.

3.24 One way to reduce energy consumption, or slow down its rate of growth, is to shift traffic from less to more efficient carriers. Coastal

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1/ Where indirect energy flows for the manufacture and maintenance of vehicles, and the construction, operation and maintenance of fixed transport infrastructure such as roads, airports, railway tracks, ports are included, transport may account for a further 10 percent or so of energy use.

shipping, river and rail systems are several times as energy efficient as road vehicles when used as heavily loaded bulk carriers. Railways are expensive to build and relatively inflexible, but even where new systems cannot be built or existing ones extended, service can be made more efficient and reliable to attract a larger part of the traffic suited to this mode. Similarly, many countries have extensive coastlines or internal waterways that could be more fully exploited. For passenger transport, improvement of the public transport services would also help in diverting part of the traffic from private cars to more efficient bus or rail services. Electrification of rail or trolley bus services can make greater use of the indigenous resources used to generate power. Better spatial planning in industry and improvements in the telecommunications system would also help to make transport more energy efficient, as would measures to increase the average load factor (for example by car pooling, better utilization of airplanes, or a reduction in the number of empty backhauls), and to improve the pattern of use (through better road traffic control, better driving techniques, improved ground operations for air transport, and so on). The proportion of freight carried by road varies greatly among developing countries, but in all of them its share has been increasing rapidly. In most, it is the dominant transport mode and likely to remain so. Thus, in many developing countries transport systems are energy intensive and largely dependent on imported oil. If savings are to be made, both in total energy consumed and in oil imports, they will be found largely by reducing the rate of expansion of road vehicles and by improving their efficiency.

3.25 Developing countries still have a much lower ratio of private cars to population or to GNP than the industrialized countries. They thus have the opportunity to avoid some of the problems that the latter are encountering in an era of high cost oil--not only heavy expenditures on oil itself but capital investment in highways. Pricing gasoline at the world price, or raising it further through taxation, is the simplest means to discourage the use of vehicles, but there are countries--especially, but by no means exclusively, the oil exporters--where the full cost of gasoline is not paid by the motorist. Pricing policy avoids the need for rationing or other physical and administrative controls which tend to result in inefficient allocations. A mix of policy measures is required, including taxation of vehicle purchases and movements, improved traffic management and road maintenance, and improved mass transit both within and between cities. Care must be taken not to discourage the use of bicycles, mopeds, jitneys and small buses, which substitute for the private car but which municipal authorities and the police tend to look upon as a nuisance.

3.26 Increasing the energy efficiency of vehicles may well be the most effective method of controlling energy consumption growth in the transport sector. Its potential is much greater than that of other approaches (savings of up to 20 percent could be expected), and it generally does not affect the quality of transport services or require behavioral changes on the part of users or institutions. The design of vehicles is outside the control of many developing countries, but they can influence the choice of vehicles in particular uses and help to improve standards of operation and maintenance, especially of publicly owned truck and bus fleets. Private owners of trucks can make some adjustments to existing vehicles to meet increased fuel prices, but the rapid growth of the vehicle population and the relatively quick turnover of the road fleet offer the opportunity to make many more adjustments in a relatively short period of 5 years or so.

Potential Energy Savings in Transport

3.27 An estimate of the fuel savings that could be achieved during the next decade in the transport sector of developing countries by the various measures discussed above is given in Table 25.

Table 25: DEVELOPING COUNTRIES: POTENTIAL FUEL SAVINGS IN TRANSPORT SECTOR, 1980s
(Savings as percentage of sector's energy consumption)

	Share of Sectoral Consumption	Savings From				
		Vehicle Efficiency	Regulatory Measures	Better Use	Demand Reduction	Cumu-lative
Trucks	35 - 45	6	2	10	5	23
Buses	8 - 12	2	(.)	5	(.)	7
Private cars	25 - 35	20	2	2	5	29
Shipping	5 - 10	2	5	5	(.)	12
Air	5 - 10	20	5	5	(.)	30
Rail	2 - 5	1	(.)	5	(.)	6

(.) Less than half the unit shown.

Source: World Bank staff estimates.

If all users were able to achieve savings of the above order, total energy savings in the transport sector would be between 20 and 25 percent. As the energy used in transport comes overwhelmingly from petroleum products, this represents potential savings of about a million barrels of oil a day at present levels of consumption, costing about US$10 billion in 1980. Based on the estimated consumption and oil price in 1990, the savings in that year would be about US$25 billion (in 1980 dollars). For the oil importing developing countries, even if only about half the potential savings were actually achieved, the 1990 oil import bill would be reduced by about 10 percent.

D. Industry

3.28 Industry is a major user of commercial energy in the developing world. In countries for which data are available the industrial sector accounts for one-fifth to two-thirds of total commercial energy consumption, with an average probably at around 35 percent.

3.29 Those developing countries with relatively high levels of energy consumption 1/ are also major producers of the more energy-intensive industrial products, such as steel (Brazil, India, Republic of Korea, Mexico, Romania, Turkey, Yugoslavia), cement (Brazil, India, Republic of Korea, Romania, Turkey), ammonia (India, Indonesia, Republic of Korea, Mexico, Romania), copper (Chile, Peru, Yugoslavia, Zaire, Zambia), aluminum (Brazil, India, Yugoslavia), pulp and paper (Brazil, Republic of Korea, Mexico, Romania), fertilizers (India, Brazil, Romania, Turkey), chemicals (Brazil, India, Portugal, Romania) and refined petroleum products (Argentina, Brazil, Mexico).

3.30 Among basic products for which the industrial processes are highly energy intensive, energy intensities range widely (for example, from 0.9 to 1.5 million kilocalories per ton for cement against 8 to 11 million kcal--including feedstock--per ton for ammonia), reflecting differences between manufacturing processes. Even within product categories which may appear to be relatively homogeneous, such as cement, energy intensities differ depending on such factors as the product mix (for example different types of paper products), the basic manufacturing process (for example the "wet" or "dry" process for cement), the type of energy source (whether electricity or hydrocarbon fuels, coal or oil), and the scale of plant as well as a variety of factors under the general heading of efficiency, such as the amount of waste heat, downtime, general plant "housekeeping", and operating practices.

3.31 Another important determinant of the share of energy in total product cost is the price of energy. Energy costs and pricing policies vary among countries, and it is crucial to be aware of how they affect different industries before formulating detailed conservation policies and estimating the potential for improved energy efficiency.

1/ Of the developing market economies' total consumption of commercial energy and liquid fuels in 1978, 14 countries accounted for 70 percent and 65 percent respectively. The addition of China, Romania and Yugoslavia brings these ratios up to 85 percent and 73 percent respectively.

3.32 An energy saving program in industry can save substantial amounts of energy in the short term at relatively little cost. 1/ Bank staff experience of energy-intensive subsectors in various developing countries indicates that significant energy savings can be achieved within 2 or 3 years by improved management, personnel training in maintenance and "housekeeping", and relatively simple changes and improvements in existing production processes (such as the recovery of byproducts, or the installation of cogeneration capacity, waste heat boilers, better insulation, better bearings).

3.33 Further energy saving measures (retrofitting) involving somewhat more investment are often unique to the processes in the industry or plant concerned. Examples include coke plant dry quenching and improved preparation of raw materials in the steel industry, the conversion from wet to dry process and from oil to coal firing in cement production, shifting to autogenous processes using the heat value of ore concentrates in copper smelting, and the recovery of waste heat in refining and ammonia plants. Building new plants or expanding existing ones offers even greater scope for improving energy efficiency, since the basic design can be chosen with this in view. 2/

3.34 Tentative Bank staff estimates of the savings that could potentially be achieved, mainly by modifying existing plants in key industries, are summarized in Table 26. The table represents only the major energy consuming industrial subsectors and therefore does not represent the entire industrial sector. Moreover, the potential for energy savings in the industries included in the table depends to a large extent on the age of the plant, its scale of operation, the process used, the present condition of the production facilities, and operating practices.

1/ The US Industrial Energy Efficiency Program, undertaken by the Federal Energy Administration and the Department of Energy, found that during 1976, 1977 and 1978, the ten most energy-intensive industries improved their energy efficiency by 8 percent, 11 percent and 14 percent respectively in comparison with 1972 levels (measured as energy consumption per unit of output). These energy efficiency savings were achieved largely through short-term measures whose capital investment requirement was modest, with pay-back periods of a few weeks or months. This is not an isolated example. The International Energy Agency (IEA), reviewing the energy conservation programs of member countries, concluded that the OECD group could achieve a gross energy saving of 20-25 percent, relative to 1973 consumption levels, by 1985.

2/ Prime examples are more modern aluminum smelting capacity involving improved reduction cell design; larger and more modern blast furnaces and continuous casting in the steel industry; adoption of the Braun process in ammonia production; and more efficient secondary units in petroleum refineries.

Table 26: DEVELOPING COUNTRIES: POSSIBLE SAVINGS IN THE MAJOR ENERGY-INTENSIVE INDUSTRIES, 1980s

	LDC Percentage of World Production, 1978	Energy Consumption per Metric Ton of Output /a	Potential Savings With Existing Plant (1978 Production levels)	
			Percent	'000 bpdoe/b
Aluminum (from Alumina)	8.2	28-36	5-10	5-12
Copper (Smelted & Refined)	22.8	3-8	5-10	1-4
Steel (Crude)	9.1	4-6	5-10	40-100
Cement (Clinker)	27.4	0.5-1.0 (fuel)	15-25	60-170
"		0.2-0.3 (electricity)	5-10	7-15
Ammonia	15.1	6-8	5-15	10-40
Petroleum Refining				
Distillation	7.4	0.1	10-20	35-70
Cracking	0.7	0.1	10-20	7-15
Pulp and Paper	11.8	4-6	20-25	35-90

/a Expressed in barrels of oil equivalent, assuming that 1 kWh of electricity input requires 42,065 Kcal (10,600 BTU) of heat. This conversion factor varies widely depending on the type of primary energy, transmission losses, etc.

/b Thousand barrels a day of oil equivalent.

Sources: Production data: Metallgesellschaft, Eregli Demir Ve Celik Fabrikalari T.S.A., Cembureau, staff estimates. Energy intensity and potential savings: Bank staff estimates.

3.35 Judging by industrialized country experience, a combined program of such "housekeeping" and equipment and process changes might enable the developing countries to reduce their energy consumption per unit of industrial output by 10 percent by 1985 and 15 percent by 1990. For oil importing developing countries, assuming that the industrial sector will account for 35 percent of their total commercial energy consumption, this would imply energy savings equivalent to about 1.3 million barrels a day of oil in 1990, reducing their oil import bill in that year by about US$19 billion (in 1980 dollars) or over 17 percent.

3.36 Careful analysis is required, including energy audits at the plant level, to determine the potential for operational and physical improvements and to assess the energy savings that would result. Such audits can provide the basis for developing energy efficiency programs, including energy saving targets, training programs, operational changes and specific investments. To support such efforts at the plant level, broader policy changes may be needed in energy pricing, fiscal incentives for energy saving investments, government-supported technical assistance programs, and provision of funds on attractive terms.

3.37 Policies toward industrial development need to take account of the higher direct cost of energy in industrial production (now 20-35 percent of total product cost in steel, 30-35 percent in cement, 40-50 percent in ammonia, for example). This does not imply that developing countries should move away from investments in energy-intensive industries. Considerations other than energy, such as the comparative advantage conferred by natural resources, the extent of value added, the size of the domestic market, and the indirect costs of energy as an element in transport costs, will obviously continue to be important and their implications weighed case by case. As an example, the possibility of producing methanol or ammonia economically from supplies of natural gas that exceed domestic needs, has already been noted in Chapter II. As well as the energy directly used in production, policies to influence the product mix in industry need to consider the uses to which products will be put. Aluminum, for example, is more energy intensive than steel, but vehicles in which aluminum is substituted for steel, being lighter, are likely to use less fuel.

E. Electric Power

3.38 The use of power has grown along with the development process, at a rate of 10.4 percent a year from 1950-74, and 11 percent a year since then. Power consumption growth is projected to slow down somewhat, to an annual rate of 8-9 percent during the 1980s. A continually greater proportion of developing countries' commercial primary energy consumption has been used to produce electricity: until the 1950s this share was 10 percent, and by 1980 it had reached 25 percent. Bank staff projections, which are somewhat conservative, indicate that it will surpass 30 percent by 1990 (see Table 27).

Table 27: DEVELOPING COUNTRIES: COMMERCIAL ENERGY USED TO PRODUCE ELECTRICITY, 1980-90
(Million barrels a day of oil equivalent)

	1980	1985	1990	Average Annual Percentage Growth 1980-90
Thermal				
Oil	1.44	1.84	2.06	3.7
Gas	.29	.70	1.13	14.6
Coal/Lignite	.81	1.36	2.15	10.3
Subtotal	2.54	3.90	5.34	7.7
Hydro /a	2.10	3.13	4.11	6.9
Nuclear /a	.08	.27	1.20	31.1
Geothermal /a	.01	.05	.08	23.1
Total	4.73	7.35	10.73	8.5
Note: Percentage of Total Commercial Energy Consumed in Electricity Production	25	29	31	

/a Valued at the thermal input required to generate an equivalent amount of electricity.

Source: Bank staff estimates.

3.39 Worldwide, utilities have made a dramatic shift in policy away from the use of fuel oil to coal and gas. Nevertheless, in 1980, developing countries will use nearly 1.5 million barrels of oil a day, at a cost of around US$16 billion, to generate electric power. Their oil consumption for generating electricity is projected to increase to over 2 million barrels a day at a cost of US$30 billion (in 1980 dollars) in 1990.

3.40 Most developing countries urgently need to increase the efficiency of their energy use in electric power generation, transmission and distribution. All power systems inherently incur energy losses in generating stations, and resistance losses in transmission and distribution networks. Generating stations typically use the equivalent of 1 to 6 percent of the energy they produce, with hydro plants at the lower end of the scale and coal-fired plants at the upper. New plants can be designed to maximize their energy efficiency, but there is also scope for reducing station consumption through retrofitting with more efficient plant elements and controls, and through improvements in operating procedures and better maintenance. Resistance-type losses in the transmission and distribution networks of developing countries at present consume about 15 percent of their total power production. Since optimal loss levels are approximately half that, new efforts are needed to rehabilitate transmission and distribution networks, install new conductors, improve system operations and upgrade system dispatch facilities. More efficient operations and a reduction in losses might realistically reduce the requirement for new capacity in 1990 by 7 percent, corresponding to a saving of US$20 billion (in 1980 dollars); the potential fuel saving might be as much as US$2 billion a year.

3.41 Interfuel substitution provides additional possibilities for reducing oil import requirements in the power sector. The scope for interfuel substitution in existing plants is partly determined by technical characteristics, as was discussed in Chapter II. For example, gas can replace oil as a generating fuel in all types of thermal plants, with relatively inexpensive modifications. However, as noted in that Chapter, the potential for substituting coal is much more limited, because of the difficulty of converting existing boilers to coal. Because the economic threshold for steam units is 30 MW, small systems will continue to require imported diesel oil as a fuel, unless hydro resources are available.

3.42 The development of national grids and regional interconnections also offers promise of increasing the efficiency of primary energy use in the developing countries. Large power systems permit economies by being more easily able to handle different load, time, seasonal and hydrological factors. In thermal generation, larger unit sizes have lower capacity costs and greater efficiency, lower reserve margins, and cheaper maintenance requirements. Regional interconnections can make possible the optimal development of very large hydro projects, or can stimulate complementary use of hydro and thermal resources. Larger integrated systems made possible by the regional approach may in the future result in greater savings from new station design, incorporating additional heat recovery measures, more efficient steam conditions, and compound cycles. Such measures may be expected to yield gradual improvements in conversion efficiency (heat rate) from a present average of about 28 percent to 35-40 percent. Compared with the continuation of present practices, this would result in annual fuel savings equivalent to about 12 million tons of oil equivalent by 1990. All the factors noted above should by 1990 result in fuel savings of the equivalent of over 700,000 barrels a day.

F. Summary of Potential Savings

3.43 Developing countries could achieve substantial benefits by a broad program of demand management designed to increase the efficiency of energy use. Their energy consumption in 1990, presently projected at 30.6 million barrels of oil equivalent a day, could be reduced as much as 15 percent by such a program. Not only could some of the benefits be derived within a short time, but many of the measures involved require little or no investment; an example is the removal of government price regulations which in many countries (industrialized and developing) prevent the economic pricing of energy products. The greatest scope for curbing the growth of energy demand is in the industrial sector, which is a major consumer of electric power as well as mineral fuels, mainly through the planning of industrial development, technical improvements in industrial processing, and retrofitting. Sizable energy savings could also be achieved in transport (particularly of oil), in the electric power industry and in the household sector. Programs of this kind call for difficult political decisions on the part of governments, as well as administrative and technical skills which are very scarce in many of the developing countries. This is an area where the international community, including both aid agencies and private industry, could be particularly helpful.

3.44 Tentative estimates of the energy savings that might be achieved in the developing countries by various measures of demand management by 1990 are set out in Table 28. These estimates are based on judgments by Bank staff

Table 28: DEVELOPING COUNTRIES: POTENTIAL SAVINGS IN ENERGY CONSUMPTION, 1990
(Million barrels a day of oil equivalent)

		Savings From				
	Projected Consumption /a	Pricing Policies	Taxes and Regulations	Retro-fitting & Technical Improvements	Interfuel Substitution & Scale Economies	Total Reduction
Electric Power /b	6.5	0.1	(.)	0.5	0.1	0.7
Agriculture	1.5	(.)	(.)	0.1	(.)	0.1
Households	5.9	0.3	0.1	0.1	0.4	0.9
Transport	7.5	0.1	0.1	0.6	0.2	1.0
Industry	8.7	0.2	0.2	1.1	0.3	1.8
Other	0.5	0.1	(.)	(.)	(.)	0.1
Total	30.6	0.8	0.4	2.4	1.0	4.6

(.) Less than half the unit shown.

/a Based on "High Case" projections of GNP and 3 percent per year increases in oil prices as in World Development Report, 1980; a ratio of energy consumption to GNP growth of 1:1.2; and a price elasticity of energy consumption of -0.3 percent.

/b Includes electric power consumed in generation, station use, losses in transmission and distribution. Electrical energy (based on thermal value) is distributed among the various sectors in the Table.

Sources: Projected consumption from Table 1; Savings from Bank staff estimates.

derived from country, sectoral and project analysis in developing member countries. The reductions in energy demand shown in the Table are believed to be achievable without affecting the GNP growth rates projected for these countries in World Development Report, 1980. If these potential savings could be achieved, the growth in the developing countries' consumption of energy, now projected at 6.2 percent a year between 1980 and 1990, would be reduced to about 4.5 percent a year. The ratio of energy consumption to GNP growth in the decade ahead would remain at about 1:0.8. For the oil importing developing countries savings of oil imports, which are likely to represent about 60 percent of total energy savings, combined with the increased oil production assumed in Case 2 (Table 9), would reduce their oil imports in 1990 by 40 percent, or a saving of US$45 billion in 1980 dollars.

Chapter IV: A WORLD BANK PROGRAM FOR ENERGY DEVELOPMENT 1/

4.1 The large majority of developing countries are facing an energy crisis of major proportions, which affects all aspects of their development programs and manifests itself in problems at several levels. The higher cost of energy affects the balance of payments and restricts imports for other investments and productive inputs. It requires:

- much higher levels of investment for energy production than before;
- the reorientation of development plans to take account of this newly scarce and expensive factor of production;
- substantial investments in energy conservation;
- a massive effort to ensure that the minimal fuel requirements needed by the rural and urban poor can be met in the next two decades.

All of these demands will put a heavy burden on the already scarce supply of high level technical and managerial manpower as well as on capital resources. Because of its pervasive nature, affecting all aspects of production and all facets of resource use, the energy problem is central to the development prospects of many countries. It is urgent that they receive the financial and technical support they need to expand their energy output and to manage their energy use efficiently.

A. Present World Bank Lending for Energy

4.2 In response to the changed situation in world energy markets, the Bank extended its energy operations from the power and coal sectors and in 1977 began to assist member countries with petroleum development. Early in 1979 an Accelerated Program was approved which included financing for exploration as well as production. 2/ The preparatory work and visits to a number of countries, backed by a comprehensive survey undertaken by consultants, had confirmed that many countries possessed potential petroleum resources yet to be discovered. It also revealed the lack of information

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1/ References to the World Bank include the International Development Association, and those to Bank loans include IDA credits. Activities of the International Finance Corporation are discussed in IFC Five-Year Program: FY81-85 (IFC/R80-55).

2/ "A Program to Accelerate Petroleum Production in the Developing Countries", World Bank Report No. R78-262, November 30, 1978, hereafter referred to as the 1978 Report.

about resources, the very limited survey and exploratory work that had been done, and the scale of technical, administrative and financial help that would be needed.

4.3 Since the inception of the current energy program the Bank has financed 18 petroleum projects in 16 developing countries. Forty-nine developing member countries have been visited by Bank missions, and in 38 of these one or more projects have been identified. Of the 18 projects approved, 9 are mainly for predevelopment activities, including technical assistance, geological and geophysical surveys, and exploratory or appraisal drilling. Nine are mainly for production. Several projects contain more than one component. The Accelerated Program and the actual and planned programs for FY79-81 are summarized in Table 29.

Table 29: COMPARISON OF ACCELERATED AND ACTUAL WORLD BANK OIL AND GAS PROGRAMS, FY1979-81

	Actual /a FY79-80	Planned FY81	Actual & Planned FY79-81 /a	Accelerated Program FY79-81
Surveys: Number of Countries /b	12	16	28	13
Lending: Number of Operations				
Exploration Promotion	5	13	18	/c
Exploratory Drilling	2	3	5	8
Appraisal Drilling	2	1	3	9
Production	9	8	17	24
Total	18	25	43	41
Lending: Million US Dollars	643	705	1,348	1,550
Professional Staff /d	32	38	38	35

/a Includes Bombay High project approved in June 1977.
/b Includes technical assistance.
/c Not a category in the Accelerated Program.
/d At end of period.

There has been a greater concentration on predevelopment work than had been expected, and less on production. Of the seven production projects, 4 are for natural gas production, transport and distribution facilities, and the remaining 3 are oil production projects, which include components for the rehabilitation of producing fields (Peru) and for new production (India and Pakistan). Two loans have been made for project engineering, and one of these has since been refinanced in a subsequent production loan. Because predevelopment projects are less costly than production projects, loan commitments are smaller than the amounts projected in the Accelerated Program.

Energy Sector Reviews

4.4 The 1978 Report noted that some 60 oil importing developing countries needed help in devising national energy plans and argued that the Bank's program of energy work should be expanded. By identifying policy issues and priorities for action, energy sector reviews help provide member governments with impartial advice on energy questions. They also further the Bank's own work, by enabling the energy sector to be integrated into country economic work, by identifying energy sector projects and needs for technical assistance in national energy planning, and by providing a basis for programming Bank lending activities when the Bank lends concurrently to several energy subsectors. Five energy sector reviews were carried out in FY79 and 14 were substantially completed in FY80. Eight of the 19 countries concerned rely on imported oil for more than half of their commercial energy needs and six others have also been seriously affected by the rise in prices; three are oil exporters (Egypt, Indonesia and Nigeria).

Oil and Gas Production Projects

4.5 The results expected from the production projects now being implemented are shown in Table 30. The estimated economic rates of return in these projects are as high as forecast in the 1978 Report -- none is below 30 percent and most exceed 50 percent. Most of these production projects also provide for future predevelopment and exploratory work. Fifteen of the 18 loans made so far have been in countries whose potential is rated High or Very High, 1/ and 9 of these are for the development of resources already discovered by foreign and/or national oil companies. Of the predevelopment projects, several have been in less promising countries, mainly to develop data to attract foreign companies; the large majority of countries in this category need considerable assistance in promoting projects that would attract foreign interest.

1/ As defined in the 1978 Report; that is, with potential oil and natural gas resources of over 750 million barrels of oil equivalent.

Table 30: SUMMARY OF RESULTS EXPECTED FROM WORLD BANK OIL & GAS PRODUCTION PROJECTS /a

	Output on Project Completion (Barrels/day)	Output as Percentage of Domestic Commercial Energy Demand	Estimated Rate of Return (Percent)
East Asia			
Thailand Gas	130,000	10-16	53
South Asia			
India (Bombay High)	102,000	14	66
Pakistan (Toot)	11,250	8	56
Middle East			
Egypt (Ras Shukheir)	3,800	1.4	32
Egypt (Cairo Gas Distribution)	n.a.	n.a.	44
Tunisia (Gas Transmission)	n.a.	n.a.	50
Latin America			
Peru (oil)	20,000	14.3	over 100

n.a. Not applicable.

/a Excludes two engineering loans (to Thailand and Turkey).

Source: IBRD appraisal and supervision reports.

Predevelopment Work in Oil and Gas

4.6 The demand for assistance in predevelopment work has been much larger than expected. Twelve of the 17 loans/credits approved in FY79 and FY80 include provision for the financing of surveys, against an original estimate of five. In Argentina and Peru, seismic surveys are being financed to open up new areas for exploration by the national oil company alone or in association with a foreign company. Projects in Congo, Nepal and Yemen PDR will provide the first thorough reconnaissance of areas that have not so far been surveyed systematically; others in Honduras, Madagascar and Somalia will help to reinterpret exploration data already available. In four countries -- Bolivia, Morocco, Pakistan and Tanzania -- surveys will support exploratory or appraisal drilling programs undertaken by national oil companies with financial support from the Bank. The principal reason for the Bank to finance geological and geophysical surveys in developing countries is to generate accurate information which would either enhance their prospects of attracting foreign risk capital for exploration on favorable terms, or enable national oil companies to mount well-prepared drilling programs.

4.7 The need for predevelopment assistance will continue to be high for the next few years, but should shift gradually from technical assistance and exploration promotion to the support of drilling programs based on earlier surveys financed by the Bank or others.

4.8 As part of the lending for petroleum, assistance has also been provided in national energy planning, in financing studies of alternatives to existing sources of energy, and in technical assistance to the government. Special attention has been given to pricing policies, and improvements in the structure and level of prices have been agreed with some governments in the course of loan negotiations. In other cases, pricing studies have been financed which should lead to more rational pricing policies in the future.

Oil and Gas Exploration

4.9 The approach used in the recent petroleum exploration project in Morocco (ref R80-66) is to identify leads for exploration in an area that has not yet been explored, and to complete the exploration of a basin in which discoveries have been made but have not yet attracted foreign oil companies. Exploration will be undertaken in stages, in well-defined limited areas, and the results will be carefully evaluated before exploratory wells are sunk. This approach could be followed in a number of countries with experienced national oil companies and where a potential for petroleum development exists. Examples are Argentina, Bolivia, Brazil and Chile in Latin America; Egypt, Syria, Tunisia, Turkey and Yugoslavia in the Mediterranean area; and India, Indonesia, Malaysia, Pakistan and the Philippines in Asia.

4.10 The recent exploration project in Tanzania (ref R80-97) is an example of the assistance the Bank can provide to countries which do not have an experienced national oil company, but in which an existing lead has been relinquished by an international oil company, either because the prospect was not judged to be economical at the time or for other reasons. Benin, Chad, Ghana, Ivory Coast, Senegal and Somalia are among countries which offer similar prospects for Bank assistance.

Coal

4.11 As a part of the Accelerated Program for fuel minerals which was approved in early 1979, an IBRD/IDA lending program was proposed for coal, as shown in Table 31, which also shows the projects actually financed in FY79 and 80, and the program for FY81.

Table 31: WORLD BANK COAL AND LIGNITE PROGRAM, FY1979-81
(Numbers of activities)

	FY79 and FY80		FY81	
	Originally Proposed	Actual	Originally Proposed	Current Estimate
Sector Studies	9	10	2	2-3
Engineering Loans	1	0	1	2
Production Loans	3	1	3	2
Bank Lending: Million US Dollars	160	72	115	230

The lower than projected level of operations in FY79-80 was due to the relatively slow growth of coal development worldwide, and to the long time it takes to prepare a coal project. In FY79 and 80, Bank missions reviewed the coal sector in 10 developing countries (Afghanistan, Argentina, Brazil, Colombia, Indonesia, Madagascar, Mexico, Philippines, Thailand and Viet Nam); the sector work has led to follow-up projects in all but three cases. One production loan to Thailand for US$72 million was approved; two project loans, one each to Indonesia and Brazil, and two engineering loans, one each for Argentina and Colombia, are scheduled for FY81, for total lending of about US$230 million. In addition, two to three subsector studies are planned for FY81, including one in India.

Electric Power

4.12 World Bank lending for the generation and transmission of electric power was rather stable in the period FY76-79 but increased substantially in FY80, an exceptional year. The breakdown of activities is summarized below:

Table 32: WORLD BANK ELECTRIC POWER LENDING, FY1979-80
(Million current US dollars)

	FY1976-78 Annual Average	FY79	FY80
Hydro	247	183	782
Coal/Lignite Thermal	150	495	840
Oil Thermal	94	24	0
Gas Thermal	4	219	57
Geothermal	6	9	40
Transmission and Distribution	439	191	580
Rural Electrification	74	234	93
Total	1,015	1,355	2,392
Note:			
In Constant 1980 US Dollars	1,307	1,458	2,392
Number of Projects	19	19	25

The Bank's lending for electric power generation is increasingly emphasizing hydro and coal-fired thermal plants. In FY80 alone, the Bank financed 4,847 MW of new hydropower capacity, as much as in the previous four years. In that year there were no oil-fired thermal projects, and gas-fired thermal projects accounted for only 6 percent of the total thermal generation capacity financed; oil- and gas-fired thermal projects contributed 39 percent on average in FY1976-78. Several large power projects have been successfully co-financed by the Bank in association with official and private funds, and such projects continue to be attractive to cofinanciers.

B. An Expanded World Bank Program for FY1981-85

4.13 The World Bank is by far the largest source of public support for energy development in developing countries -- particularly for energy sources other than electric power. In some subsectors, the Bank is virtually the only agency providing both technical advice and financial assistance. While it is highly desirable that other agencies expand their efforts, the key role which the World Bank presently plays in the energy sector of developing countries and the very large investment requirements which lie ahead in those countries are the basis for proposing a further expansion of the Bank's program in this vital sector.

4.14 The lending program currently planned for energy in FY 1981-85 is shown in Table 33; it amounts to US$13.0 billion or about 17 percent of the Bank's total lending commitments planned for the five-year period. Based on a country-by-country review of investment needs and opportunities in the energy sector, it is clear that a substantially larger program would be both feasible and desirable. The "desirable" program, also shown in Table 33, of US$25 billion, is US$12 billion larger than the program presently planned and, without additional resources, cannot be financed by the Bank. The "desirable" program can readily be justified in terms of the energy investment requirements of the developing countries, and in terms of projects with high rates of return likely to be available for financing. It assumes no change in the Bank's policy on cost sharing, or in its efforts to attract cofinancing. But to accommodate such a program within the presently approved Five-Year Lending Program -- it would amount to over 30 percent of the total, compared with the current program's 17 percent -- would seriously distort the sectoral balance. The Bank would no longer have the appropriate capacity to support the other important development objectives of its members such as those in agriculture and rural development, health and water supply, education and training, industry and transport.

Table 33: CURRENT AND DESIRABLE WORLD BANK ENERGY LENDING PROGRAMS, FY 1981-85
(Million current US dollars)

	FY81	FY82	FY83	FY84	FY85	Current FY81-85	Desirable FY81-85
Coal and Lignite /a	230	40	230	230	110	840	2,000
Oil and Gas							
Predevelopment	120	180	320	160	240	1,020	2,410
Oil Development /b	255	260	350	300	590	1,755	3,320
Gas Development /c	210	285	345	200	170	1,210	2,270
Subtotal	585	725	1,015	660	1,000	3,985	8,000
Refineries	0	150	0	0	0	150	1,000
Renewables							
Fuelwood	50	75	100	100	100	425	1,100
Alcohol	0	175	25	0	0	200	650
Subtotal	50	250	125	100	100	675	1,750
Electric Power	1,390	1,405	1,470	1,670	1,655	7,590	11,000
Industrial Retrofitting	0	0	0	0	0	0	1,250
Totals:							
Current Program	2,255	2,570	2,840	2,660	2,865	13,190	
Desirable Program	2,650	3,750	4,950	6,500	7,150		25,000

/a Includes coal gasification projects.

/b Includes heavy oil projects.

/c Includes methanol.

The Desirable Program

4.15 The present program includes US$4.0 billion for oil and gas predevelopment and production projects. An additional US$4.0 billion of activities can already be identified tentatively. Even the US$8.0 billion shown for oil and gas development in the "desirable" program would not exhaust the prospects of fruitful investment in this sector. About 30 percent of the US$8.0 billion lending for oil and gas would be for predevelopment such as surveys and exploratory drilling. As the financing of predevelopment activities in oil and gas by the Bank and from other sources continues to grow, so will the requirements for production investment. For coal, the "desirable" lending program, including increased financing for exploration and project preparation, would support a near doubling of coal output in the developing countries by 1990. The additional financing for electric power, amounting to US$3.5 billion, is fully justified by country needs and the Bank's capacity to identify projects. All of the generating projects in the "desirable" program have been identified. Even with this additional amount the Bank would only contribute 5.5 percent of the developing countries' investment requirements in power during the period 1981-85, compared with 3.7 percent in the current program and 9.8 percent in the previous five years. Such a program, while permitting the Bank to maintain a minimal role in large countries where it could help attract cofinancing, would emphasize: efficiency improvements in generation, transmission and distribution, including improved maintenance and rehabilitation; new or increased lending to many smaller countries that require assistance in formulating and implementing programs, to optimize power systems at the higher energy costs and to develop alternative sources of energy; and loss reduction programs.

4.16 The "desirable" program would also enable the Bank to expand substantially its lending for fuelwood, to initiate work in alcohol production from biomass, and to begin to assist members to make better use of their energy resources through the adjustment of refineries and industrial retrofitting. All of these areas are, as discussed in Chapters II and III, important to the energy prospects of the developing countries and likely to become more so. In addition to the projects already identified in these areas -- and included in the US$25 billion program -- more will undoubtedly be identified in the next several years as developing countries improve their energy planning and analysis of their future energy prospects, conservation receives the emphasis it deserves, and the technologies for renewable energy continue to evolve.

4.17 The inadequacy of present resources to finance an appropriate energy program in the developing countries led to the suggestion in the recent communiqué of the Venice Summit, which asked:

> "the World Bank to examine the adequacy of the resources and the mechanisms now in place for the exploration, development and production of conventional and renewable energy sources in oil-importing developing countries, to consider means, including the possibility of establishing a new affiliate

> or facility, by which it might improve and increase its lending programs for energy assistance, and to explore its findings with both oil-exporting and industrial countries."

Many aspects of such an affiliate or a facility will have to be considered, including the availability of additional financial resources from OPEC and OECD countries, the financial structure, organizational arrangements, ownership and management, relationship to the Bank, and scope of operations. On all these matters the views of potential contributors would be important and these can be assessed only in the course of discussions with them.

4.18 We would hope to bring to the Board later this year our preliminary conclusions regarding an energy affiliate. While many of the elements of such a proposal are not yet defined, the principal objective should be clear: additional resources to finance energy investments beyond the levels now proposed for the Bank's FY81-85 program. Its resources must be adequate to sustain a level of operations appropriate to the capital requirements of the sector. A new affiliate or facility would be justified only if its resources were additional and substantial.

4.19 Although the Bank does not now have the resources to finance a US$25 billion program in energy for FY81-85, we would plan to work toward such an expanded program while discussions on the sources of additional financing proceeded. We would plan to increase the FY81-82 energy program modestly to accommodate increases in predevelopment and production in oil and gas, expand the fuelwood program and undertake some initial operations in production of alcohol from biomass and in industrial conservation. Such projects, with Bank Group financing of approximately US$500-1,000 million, can probably be incorporated in the lending program for the next two years in response to evolving country priorities -- that is, in substitution for projects presently planned in other sectors.

C. Operational Aspects of the World Bank Energy Program

Sector Reviews

4.20 An expanded program of energy sector reviews is planned to assist oil importing developing countries in devising energy plans and to support the Bank's lending program in FY81-85. During the first half of this period 40 energy sector reviews will be carried out, of which 26 will be in countries which depend heavily on imported oil. With the completion of these reviews, and those already carried out in FY79-80, the Bank will have covered most of the 60 oil importing developing countries believed to be in need of assistance in energy planning. Several studies of energy subsectors within countries will also be made during this period. The program of energy sector reviews will be continued in the following years, in part to cover other countries in which the Bank proposes to lend, and in part to update reviews made earlier. The energy situation is constantly changing and the information on country needs and prospects must be reassessed at regular intervals.

4.21 Assistance will also be given to member countries on a wide range of energy questions including, for example, the formulation of exploration policies, the choice of technologies, resource and market surveys, training, and advice on contracts with foreign companies and other legal matters. Where possible, assistance will be included as components of energy loans or credits, but on occasion a separate technical assistance loan or credit, comprising several of the activities mentioned, may be appropriate.

Promoting Oil and Gas Exploration

4.22 The objective of the Bank's program in predevelopment work for oil and gas would continue to be to accelerate exploration in countries where present levels are inadequate and to help prepare technical data to permit decisions on exploration priorities. This involves both support for technical operations and assistance in attracting potential foreign investors.

4.23 Projects to promote exploration are designed to assist countries in a) gathering and interpreting past exploration data; b) carrying out additional survey work to supplement the existing data base or confirm leads; c) reviewing existing legislation and contractual frameworks; d) ensuring competition among companies on critical parameters including work commitments and durations; and e) negotiating exploration agreements and monitoring exploration activities. These projects are designed to lead to tenders for exploration, usually 6-12 months after the approval of the loan or credit. The average cost of exploration promotion projects is estimated at around US$5-8 million, largely in foreign exchange. The demand for this type of assistance is expected to continue to be high.

4.24 Experience to date also suggests that the exploration process is a continuum and that boundaries between various types of activities -- surveys, exploratory and appraisal drilling -- are not as clearly marked as was suggested in the 1978 Report. Exploration promotion projects, for example, usually contain several phases of exploration work, and there is often uncertainty as to the timing and likelihood of the follow-up production phase. Therefore, the policy of setting a 10-year term for loans for such activities, on the model of engineering loans, has not proved appropriate. In future operations we therefore propose to apply standard IDA terms or the relevant Bank country terms to predevelopment loans and credits. Where warranted, provision would be made for refinancing the loan in any subsequent production operation. These terms would apply also to predevelopment loans for coal.

4.25 In exploration, we shall seek to maximize participation by private companies which have traditionally provided risk capital and the necessary know-how. However, in some cases, as envisaged in the Accelerated Program, international oil companies may seek the presence of the Bank at the exploration stage, or the Bank may be requested to participate in financing exploration programs undertaken jointly by private and national oil companies, or by national oil companies alone.

4.26 When only the Bank presence is required, we shall seek to expand the use of the "Letter of Cooperation", as used in Pakistan in support of an exploration program by Gulf Oil. This letter only commits the Bank Group to consider financing developments which may result from exploration activities. But its basis is a review by the Bank of the proposed program for exploration and the arrangements between the company and the government. The Gulf Oil letter was subsequently extended to British Petroleum and four additional such letters are under discussion. It is likely that as improved data and incentives attract additional interest in exploration, the use of this device will expand, particularly where companies are entering countries for the first time. However, in some cases the letter of cooperation may not provide adequate Bank participation. If necessary, we would be prepared to consider a loan to the local subsidiary of an oil company with the full commercial and technical guarantee of the parent company. The basic criterion in all cases would be an expansion of exploration activity with the largest possible participation of other sources of capital, particularly private oil companies which command the technical expertise that is essential.

4.27 The 1978 Report also envisaged Bank loans to finance a government's share of an exploration program undertaken jointly with an oil company or by the national oil company alone. So far no such opportunities have arisen, possibly because joint exploration arrangements between a host government and a major oil company are rare. But it may also be that some countries, particularly the smaller and poorer ones, may not consider it appropriate to borrow funds to be used for exploration venture capital. Although our limited experience to date has not provided evidence that this is a problem, the need for such financing may have to be considered further as exploration possibilities in developing countries are expanded through the increase in geophysical data.

4.28 In FY80 the Bank financed three projects for exploration/appraisal programs undertaken by national oil companies (in Bolivia, Morocco and Tanzania). The main objectives of these projects were to open up new areas which had not been explored, to assess oil shows or to prove up gas reserves required for an export project. It is expected that a number of countries will request similar assistance in the future.

Oil and Gas Production

4.29 The investment requirements for oil and gas production are high, and private capital will be important in meeting these requirements. The Bank will seek to maximize the technical, institutional and policy support associated with its financing, and to assist both in strengthening national oil companies and in the design and implementation of adequate sector policies. Bank assistance to governments or national oil companies will be particularly important in a) ensuring that adequate feasibility studies are carried out for the rehabilitation of oil fields, in attracting cofinancing, and providing financial support for field development; b) promoting preinvestment work, pilot plant development, and investment in secondary recovery projects; c) the assessment of marginal fields which have not attracted private oil companies, due to their small size in relation to the cost of production facilities and infrastructure (transmission); and d) in the identification and development, including related infrastructure, of natural gas reserves. In addition, the

Bank may participate in the financing of export oriented projects, such as LNG plants and international oil and gas pipelines, to help mobilize private capital.

Coal Exploration and Production

4.30 Exploration and prefeasibility work are required to identify and delineate coalfields and examine their suitability for development. In developing countries with no meaningful inventory of coal resources, a general review of the information in existing geological reports is required. In areas judged to have a good potential for coal, and where no initial drilling or trenching has been done, programs to prospect for coal can then be designed. Depending on the size of the region, such programs would require a period of up to two years, and cost up to US$20 million per country. Where promising coal deposits have been identified, exploratory drilling and evaluation are required. This would require a further 1-2 years and US$1-15 million per country depending on the size and complexity of the region being investigated. Based on the results of exploratory drilling, preliminary engineering and feasibility work including initial project scope and design may be required. Coal projects require large investments. Developing new coal projects or expanding or rehabilitating existing mines requires studies of engineering, market, economic, and financial aspects of the mine itself and of coal preparation and transport facilities. Such studies may take 1-5 years to complete and cost up to US$20 million, depending on the size and complexity of the project.

4.31 Many developing countries lack the technical skills to investigate the increased use of coal. Several have large coal reserves whose development has lagged, because their domestic markets are small and export prospects have been uncertain. They require assistance to carry out utilization studies, to investigate export opportunities and to analyze the potential for fuel substitution in the industrial sector. The Bank will: a) review existing geological reports of coal resources in some of the more promising countries which lack a systematic inventory of coal deposits; b) be prepared to finance basic exploration programs in countries with promising coal resources; c) provide technical assistance to reevaluate the results of previous preinvestment studies which have not resulted in projects; d) finance feasibility studies and engineering work to prove reserves; e) finance studies to identify prospects for increased use of coal, particularly in the power, industrial and household sectors, and f) finance coal mining and transport projects for domestic coal use and exports.

Other Energy Sources

4.32 Renewable energy holds considerable promise for the developing countries, and should therefore occupy an important place in the Bank's program for energy. The proposed program will be shaped by the potential of various renewable energy resources in the medium term, and the readiness of various technologies for application in developing countries. It includes increased lending, sector work and research.

4.33 The program's main focus is on increasing production of fuelwood. Technically and economically sound approaches to both reforestation and more efficient use of fuelwood are available and the Bank has substantial experience in forestry operations. The fuelwood program would concentrate on expanding planting and production, strengthening sector institutions, training manpower, and testing technical inputs and extension techniques. The introduction of more efficient stoves and improved charcoaling techniques would be included in as many projects as possible. Some relatively small pilot projects intended mainly to build up technical and economic infrastructure for fuelwood development, would be designed as technical assistance projects. While there is a clear need for Bank assistance and requests from a number of governments have already been received, lending for alcohol production must be approached with caution. Operating experience is lacking outside Brazil, and the true economic costs of producing the biomass to be used as feedstock must be carefully assessed in each country, taking account of possible competition for land between food and fuel.

4.34 Other types of renewable energy, including solar thermal and electric technologies, hydro and wind power from small units, and other applications of biomass and biogas technologies, are capable of meeting a variety of energy needs in both the traditional and the modern sectors of developing countries. Given the technical and economic uncertainties and the Bank's lack of experience in this area, the Bank will seek to gain operational experience with the most promising technologies and to build local capacity in developing countries to design and implement future programs. The main opportunities for incorporating these technologies in Bank projects are in: a) power projects for small-scale decentralized generating facilities, including wood-fuelled and small hydro plants; b) biogas and solar components in rural development projects, to meet household and community needs; c) use of biomass fuels in converters, and more modern forms to meet in-plant needs in industrial and agroindustrial projects; and d) the production of equipment to harness renewable energy in developing countries. Lending for such experimental and demonstration activities is included in the subsectoral programs, for example for electric power and industry.

4.35 The limited amount of lending that may be required for synthetic fuels would be accommodated within the coal and natural gas programs. In countries with natural gas deposits more than adequate for domestic demand, and for which there are no immediate export prospects, consideration will be given to preparing methanol projects. In countries with a substantial coal base that could be used for industry, coal gasification projects would be attractive; an engineering project for coal gasification is proposed in Turkey in FY81 with a follow-up investment phase in FY84. One other loan for coal processing is included in FY85.

ANNEXES

ANNEX I

Table I.1: WORLD PROVEN OIL AND GAS RESERVES, BY COUNTRY, 1 JANUARY 1980

(Million barrels of oil equivalent)

	Oil	Gas: Associated	Gas: Non Associated	Gas: Total
DEVELOPED MARKET ECONOMIES				
Australia	2,130	..	..	5,270
Austria	141	..	..	70
Canada	6,800	..	..	14,530
Denmark	375	..	..	480
France	50	..	..	1,070
Germany, West	480	..	..	1,080
Greece	150	..	..	680
Israel	1	..	..	20
Italy	645	..	..	600
Japan	55	..	..	100
Netherlands	60	..	..	10,100
New Zealand	110	..	..	1,020
Norway	5,750	..	..	4,000
Spain	150	..	..	340
United Kingdom	15,400	..	..	4,250
United States	26,500	..	..	37,380
Subtotal	58,797			80,990
CENTRALLY PLANNED ECONOMIES				
China	20,000	..	..	4,490
USSR	67,000	..	..	161,740
Others	3,000	..	..	1,800
Subtotal	90,000			168,030
DEVELOPING COUNTRIES /a				
Net Oil Exporters				
Algeria	8,440	1,440	22,434	23,874
Angola	1,200	216	..	216
Bahrain	240	..	..	1,530
Bolivia	150	60	1,020	1,080
Brunei	1,800	..	..	1,308
Burma	25	..	..	20
Congo	400	48	384	432
Ecuador	1,100	162	99	261
Egypt	3,100	420	522	942
Gabon	500	..	..	80

	Oil	Gas		
		Associated	Non Associated	Total
Net Oil Exporters (cont.)				
Indonesia	9,600	..	..	3,858
Iran	58,000	..	..	83,250
Iraq	31,000	..	..	4,670
Kuwait	68,530	..	..	5,690
Libya	23,500	..	..	4,080
Malaysia	2,800	180	4,020	4,200
Mexico	31,250	3,720	10,026	12,336
Nigeria	17,400	..	..	7,000
Oman	2,400	..	..	340
Peru	655	102	216	318
Qatar	3,760	..	..	10,190
Romania	1,667	..	..	2,000
Saudi Arabia	166,480	..	..	16,260
Syria	2,000	..	..	250
Trinidad & Tobago	700	132	1,356	1,488
Tunisia	515	60	210	270
UA Emirates	29,411	..	..	3,480
Venezuela	17,870	..	..	7,271
Zaire	135	18	300	318
Subtotal	484,628			195,827
Net Oil Importers				
Africa				
Cameroon	140	24	180	204
Ghana	7	3	7	3
Subtotal	147			207
Asia				
Bangladesh	25	..	1,680	1,680
India	1,600	450	990	1,440
Pakistan	200	..	..	2,680
Philippines	25	..	..	..
Thailand	..	..	1,360	1,360
Subtotal	1,850			7,160

	Oil	Gas		
		Associated	Non Associated	Total
Latin America-Caribbean				
Argentina	2,400	240	2,580	2,820
Barbados	1	..	..	..
Brazil	1,220	174	258	432
Chile	400	84	798	882
Colombia	710	84	858	942
Guatemala	16	..	..	..
Subtotal	4,747			5,076
Europe - Middle East				
Turkey	125	..	..	..
Yugoslavia	275	..	..	300
Subtotal	400			300
Total Oil Importing Developing Countries	7,144			12,743
Total Developing Countries	4 91,772			208,447
WORLD TOTAL	640,569			455,590

.. Not available.

/a Includes some LDCs that are not World Bank borrowing countries.

Sources: Oil & Gas Journal, December 31, 1979,
BEICIP, June 1980;
World Bank appraisal reports.

Table I.2: WORLD HEAVY OIL RESERVES, BY COUNTRY

	Estimated Oil Reserves in Place (Billion Barrels) a/	Average API Gravity
DEVELOPED MARKET ECONOMIES		
Canada	800 b/	10.5°
USA	29	8.6°-12°
Subtotal	829	
CENTRALLY PLANNED ECONOMIES		
Albania	0.5	8°
Cuba	Small c/	8°
USSR	0.02	..
Subtotal	0.52	
DEVELOPING COUNTRIES d/		
Net Oil Exporters		
Angola	0.01	18°-20°
Congo	Small c/	..
Ecuador	Medium c/	10°-20°
Gabon	0.3	15°-20°
Indonesia	0.5	15°-20°
Iran	50.0	5°-20°
Iraq	50.0	8°-20°
Kuwait	15.0	10°-20°
Mexico	3.5	15°-20°
Nigeria	0.5	15°-20°
Oman	2.0	15°-20°
Peru	1.5	..
Romania	0.02	15°-20°
Syria	3.0	8°-20°
Trinidad	0.05	8°-10°
Venezuela	2050.0	10°-20°
Subtotal	2176.38	
Net Oil Importers		
Colombia	Medium c/	10°-20°
Ghana	Small c/	8°
Ivory Coast	Medium c/	8°
Madagascar	2.0	5°- 8°
Morocco	Small c/	15°-20°
Senegal	Small c/	..
Thailand	Small c/	..
Turkey	3.0	9.7°-20°
Yugoslavia	Small c/	17°
Subtotal	5.0	
Subtotal LDCs	2,181.38	
WORLD TOTAL	3,010.90	

.. Not available.

a/ Reserve figures indicate approximate orders of magnitude only. This table represents the best estimate which can be made from the available literature.

b/ This is an average figure. Estimates range from 700-900 billion barrels. This does not include possible additonal reserves of up to 1,000 billion barrels which have yet to be fully evaluated.

c/ Medium-size reserves are of the order of 1 to 5 billion barrels of oil in place. Small reserves are less than 1 billion.

d/ Includes some LDCs that are not World Bank borrowing countries.

Sources: "Review of the World's Major Oil Sand Deposits", Oil and Sands:Fuel for the Future, Canadian Society of Petroleum Geologists, September 1974.
Phizackerley & Scott, "Major Tar Sand Deposits of the World", Bitumens, Asphalts and Tar Sands, (Chilingarian and Yen, Editors), 1978.
Walters, E.J., "Review of the World's Major Oil Sands Deposits", Oil Sands - Fuel for the Future, (L.V. Hills, Editor), 1974.
Bank staff estimates.

Table I.3: WORLD OIL SHALE RESERVES, BY COUNTRY a/
(Billion barrels)

DEVELOPED MARKET ECONOMIES	
Australia	0.25
Austria	0.01
Belgium	0.69
Canada	44.00
France	0.44
Germany, FR	2.00
Israel	0.02
Italy	-
New Zealand	0.25
South Africa	0.13
Sweden	2.50
United Kingdom	1.00
USA	2,166.20
Subtotal	2,217.49
CENTRALLY PLANNED ECONOMIES	
Bulgaria	0.13
Poland	0.05
USSR	112.60
Subtotal	112.78
DEVELOPING COUNTRIES	
Net Oil Exporters	
Burma	2.01
China	27.90
Zaire	100.64
Subtotal	130.55
Net Oil Importers	
Argentina	0.38
Brazil	800.84
Chile	0.02
Jordan	0.04
Madagascar	0.03
Morocco	0.59
Thailand	0.82
Turkey	0.02
Yugoslavia	0.19
Subtotal	802.93
Subtotal LDCs	933.48
WORLD TOTAL	3,263.75

a/ Reserve figures indicate approximate orders of magnitude only. This table represents the best estimate which can be made from the available literature.

Sources: - Budget d'Exploitation des Pyroschistes ou Schistes Bitumineux : Donnees Generales et Perspective d'avenir, Revue de l'Institut Francais du Petrole: Vol. XXVIII: 1975 (Grade of Resources listed is 10 gallons per ton and above).

- Mortveyev, A. K. Oil Shale outside the Soviet Union: Deposits of Fossil Fuels.H. G. K. Hall and Co., Boston, Massachusetts, 1974. (No minimum grade for resources listed.)

Table I.4: WORLD COAL RESERVES AND RESOURCES, BY COUNTRY
(Million tons of coal equivalent)

	Geological Resources a/	Technically and Economically Recoverable Reserves b/
DEVELOPED MARKET ECONOMIES		
Australia	262,134	27,353
Belgium	253	127
Canada	115,352	9,381
France	2,367	438
Germany, FR	246,800	34,419
Greece	895	400
Japan	8,641	1,006
Netherlands	2,900	1,430
New Zealand	790	144
Spain	2,298	537
South Africa	57,566	26,903
United Kingdom	163,576	45,000
USA	2,570,398	177,588
Others	439	115
Subtotal	3,434,409	324,841
CENTRALLY PLANNED ECONOMIES		
Bulgaria	2,633	2,203
China	1,438,045	98,883
Czechoslovakia	17,487	4,815
Germany, DR	9,400	7,660
Hungary	3,553	950
Korea, DPR	2,000	480
Poland	125,500	21,000
USSR	4,860,000	109,900
Subtotal	6,458,618	245,891
DEVELOPING COUNTRIES c/		
Net Oil Exporters		
Algeria	20	..
Angola	500	..
Bolivia	..	..
Burma	280	..
Ecuador	22	..
Egypt	80	..
Indonesia	3,723	1,430
Iran	385	193
Malaysia	75	..
Mexico	5,448	875
Nigeria	180	90
Peru	1,122	105
Romania	1,877	413
Tunisia	..	..
Venezuela	1,630	978
Zaire	73	..
Subtotal	15,415	4,084

.. Not available.

a/ Geological resources are defined as coal occurrences that at some time in the future may acquire an economic value.

b/ Technically and economically recoverable reserves are defined as coal occurrences which are exploitable under present technical and economic conditions.

c/ Includes some LDCs that are not World Bank borrowing countries.

	Geological Resources	Technically and Economically Recoverable Reserves
Net Oil Importers		
Africa:		
Benin	..	..
Botswana	100,000	3,500
Burundi	..	..
Cameroon	500	..
Ethiopia	..	..
Madagascar	92	..
Malawi	14	..
Morocco	96	..
Mozambique	400	80
Niger	..	..
Rhodesia	7,130	755
Sierra Leone	..	..
Somalia	..	..
Swaziland	5,000	1,820
Tanzania	360	..
Zambia	228	5
Subtotal	113,820	6,160
Asia:		
Afghanistan	85	..
Bangladesh	1,649	519
Brunei	1	..
Cambodia	..	..
India	56,799	33,700
Korea, PR	921	386
Lao, FDR	..	..
Pakistan	1,375	..
Philippines	87	..
Thailand	78	..
Turkey	3,268	793
Viet Nam	3,000	..
Subtotal	67,263	35,398
Latin America:		
Argentina	384	290
Brazil	10,082	8,098
Chile	4,585	162
Colombia	8,318	443
Costa Rica	..	..
Dominican Republic	..	..
Guatemala	..	..
Guyana	..	..
Haiti	7	..
Honduras	..	..
Jamaica	..	..
Panama	..	..
Trinidad	..	..
Subtotal	23,376	8,993
Europe:		
Yugoslavia	10,927	8,465
Subtotal	215,386	59,016
SUBTOTAL LDCs	232,237 d/	65,632 e/
WORLD TOTAL	10,125,264	636,364

d/ Resource subtotal includes 665 million tce in Africa, 740 million tce in Asia and 31 million tce in Latin America for those countries for which individual data are not available.

e/ Reserve subtotal includes 970 million tce in Africa and 1,562 million tce in Asia for those countries for which individual data are not available.

Sources: World Energy Conference 1977; World Bank staff estimates.

Table I.5: WORLD HYDROELECTRICITY POTENTIAL, BY COUNTRY
(Estimated gross theoretical capacity, in megawatts)

NON-OPEC OIL EXPORTERS	
Angola	11,031
Bolivia	20,547
Burma	51,369
Congo	10,319
Egypt	3,424
Malaysia	1,019
Mexico	22,684
Peru	24,921
Romania	12,300
Syrian Arab Republic	..
Tunisia	11
Zaire	150,684
Subtotal	308,309
NET OIL IMPORTERS	
Africa	
Benin	1,636
Burundi	..
Cameroon	26,210
Central African Empire	10,082
Chad	2,356
Equatorial Guinea	2,740
Ethopia	12,790
Ghana	3,550
Guinea	5,845
Ivory Coast	2,484
Kenya	12,274
Liberia	6,850
Madagascar	73,059
Malawi	91
Mali	2,410
Mauritania	1,370
Mauritius	13
Morocco	85
Mozambique	10,310
Niger	6,575
Rwanda	..
Sao Tome & Principe	..
Senegal	4,018
Seychelles	..
Sierre Leone	2,740
Somalia	165
Sudan	10,958
Tanzania	18,995
Togo	438
Uganda	16,439

Africa (cont.)	
Upper Volta	10,959
Zambia	3,500
Zimbabwe	4,566
Subtotal	253,508
Asia	
Afghanistan	4,109
Bangladesh	1,492
Fiji	..
India	63,926
Lao, PDR	..
Lebanon	..
Nepal	..
New Caledonia	..
Pakistan	23,972
Papua New Guinea	27,778
Philippines	4,473
Samoa	..
Korea, Rep,	2,265
Sri Lanka	1,078
Thailand	5,156
Turkey	..
Subtotal	134,249
Latin America and Caribbean	
Argentina	43,607
Brazil	118,556
Chile	20,228
Colombia	68,493
Costa Rica	8,652
Dominica	..
Dominican Republic	..
El Salvador	1,027
Guatemala	1,342
Guyana	16,438
Haiti	..
Honduras	548
Jamaica	..
Nicaragua	4,110
Panama	2,740
Paraguay	6,850
St. Vincent	..
Surinam	371
Uruguay	2,168
Subtotal	295,130
Total Oil Importing LDCs	682,887
Total Developing Countries	991,196
WORLD TOTAL	2,237,995

SOURCE: World Energy Conference, Survey of Energy Resources, 1974.

Annex II: DEVELOPING COUNTRIES: COMPARATIVE COSTS OF ENERGY FROM DIFFERENT SOURCES

1. Table II.1 provides a basis for comparing the costs of the various energy forms reduced to a common unit, i.e., US dollars per barrel of oil equivalent ($/b.o.e.). The assumptions used in estimating international prices of crude oil and oil products are as follows:

- The f.o.b. price of imported crude oil in Table II.1 is the reported government selling price for the so-called "marker" crude oil, Arabian Light, f.o.b. Ras Tanura;
- F.o.b. prices of imported refined petroleum products are the posted prices at the Bahrein refinery. (Price quotations for crude and refined products are based on Platts Oilgram reports of June 6 and 9, 1980);
- The f.o.b. price of liquefied petroleum gas is based on a 50/50 mixture of propane and butane with the price per b.o.e. derived from NIOC quotations.

2. All fuels are compared to crude oil on the basis of their gross average calorific value. A barrel of crude oil is taken as being a medium grade crude having a calorific value of 5.67 million British Thermal Units (BTU) or 1.4 million kilocalories.

3. Prices of products obtained by domestic refining of crude were computed as follows. To the price of crude oil, domestic or imported, is added a notional refining and distribution cost, estimated by Bank staff on the basis of costs in a "world-scale" refinery of 120,000 barrels per day capacity (6 million tons per year), to give a "total cost". The total cost includes allowances for refinery fuel and losses which the refiner must recover from sales of products obtained by straight distillation from one barrel of crude oil equivalent in grade to Arabian Light, in order to cover crude oil costs and capital and operating charges, including a reasonable return on investment. The assumed yield is: 17 percent gasoline, 15 percent kerosene, 20 percent diesel fuel, and 46 percent fuel oil. It is further assumed that ex-refinery prices for gasoline and diesel would be the same, that kerosene prices would be 1.2 times gasoline prices, and that fuel oil prices would be 85 percent of those of crude oil. This price structure, though somewhat arbitrary, reflects what the market would bear in the absence of any price control.

Liquefied Natural Gas (LNG)

5. The LNG price of US$27/b.o.e. is based on information in the March 1980 issue of Petroleum Economist. The figure is regarded as representative of the higher range of existing LNG prices but not of future prices which will be subject to negotiations.

Steam Coal

6. The imported steam coal prices include transport and handling costs for delivery to oil importing developing country consumers in a coastal location and are derived from information reported in periodicals such as Coal Week, Coal Age and International Coal Trade. Domestic coal prices are taken from these journals and from coal/energy sector studies of various LDCs. The wide range of domestic prices reflects the diversity of mining conditions, coal quality and transport linkages between mines and consumers in LDCs. The high end of the range is estimated at US$15 per b.o.e., since although mining costs and distribution costs may each reach US$10 per b.o.e. for particular projects, there are few if any examples of coal use where production and transport costs are both at the top of the range.

Domestic Production

7. a) Crude oil prices represent estimated production costs in non-OPEC developing countries from relatively small oilfields, offshore production, or enhanced recovery oil. These figures are considered to be reasonably representative for these types of production and conservative for existing production on land. A notional pipeline tariff of US$1 per barrel is added in each case to cover all costs between the field and the refiner/export terminal.

b) Natural gas prices represent the range of prices charged to indus- consumers, which have been abstracted from reports on a series of Bank projects. The range given is reasonable for new supply.

c) Domestic coal prices are taken from the coal industry publications mentioned above, supplemented by information from Bank coal and energy studies in developing countries. The broad range of both production cost estimates and distribution costs reflects the variety of conditions that exist in developing countries. The total delivered cost of coal is estimated to vary from less than US$5/b.o.e. to around US$15/b.o.e.

Synthetic Fuels

8. The estimates are based on published cost information in the trade press and reports on existing plants. Prices of gasoline and diesel derived from cracked fuel oil are obtained by adding a nominal processing charge to the price range for heavy fuel oil refined from domestic crude. Prices of gasoline and diesel derived from coal are based on published information relating to existing projects, supplemented by information obtained from engineering companies. Ethanol costs are based on estimated production costs from sugarcane or molasses in a 120,000 litres/ day plant in a country with medium capital costs. The upper end of the range assumes an ex-factory sugarcane price of US$16/ton which is roughly equivalent to the long-term projected world sugar price.

Renewable Energy

9. The estimates are made by Bank staff based on studies of renewable energy costs in developing countries.

Power Generation Costs

10. Bank estimates; Table 19 in Chapter II presents estimates of the comparative costs of power generation from various alternative sources. These estimates are based on the following assumptions: (a) Capital costs are derived from typical projects currently being undertaken by Bank borrowers; (b) A 10 percent discount rate is used to convert capital costs to annual figures; (c) Fuel costs reflect the price structures indicated in the report, except for natural gas where estimated well-head production costs are used; (d) Nuclear and coal units are assumed to operate on base load (7,000 hours/year); other plants are assumed to operate at the system loand factor (5,000 hours/year).

Table II.1

Developing Countries: Comparative Costs of Energy from Different Sources
(Notional delivered cost to OIDC consumers in coastal locations, in 1980 US dollars per barrel of crude oil equivalent)

	f.o.b. Export Cost	Transport/Processing Distribution Cost	Total Delivered Cost
I. Imported Fuels			
Crude Oil			
(Arabian Light ex Ras Tanura 6/1/80)	28.00 /a	2.75 /b	30.75
Products from above (Refined) at Point of Consumption)			
Gasoline (90R)		4.00	35.50
Household Kerosene			42.60
Diesel 53/57			35.50
Heavy Fuel Oil			27.20
Refined Products			
Gasoline (90R)	39.35	4.15 /b	43.50
Household Kerosene	41.50	4.38 /b	45.88
Diesel (53/57)	39.50	4.63 /b	44.13
Heavy Fuel Oil	24.20	3.25 /b	27.45
Liquefied Petroleum Gases			42.50
Liquefied Natural Gas			27.00
Steam Coal	6.00-8.00	3.00-6.00	9.00-14.00
II. Domestic Production			
Crude Oil - Low Cost	5.00	1.00	6.00
- High Cost	12.00	1.00-3.00	13.00-15.00
Natural Gas - Low Cost	0.30	1.95	2.25 /c
- High Cost	2.20	8.80	11.00 /c
Coal - Low Cost	2.00	2.50	4.50
- High Cost	10.00	10.00	20.00
Refined Petroleum Products (from Domestic Crude Comparable to Arabian Light)			
Gasoline (90R)		2.50	9.40-21.00
Household Kerosene			11.30-25.40
Diesel (53/57)			9.40-21.00
Heavy Fuel Oil			7.20-17.50
Liquefied Petroleum Gases			10.00-25.00
Synthetic Fuels			
Gasoline, Diesel Fuel from Cracked Fuel Oil /d			11.00-21.00
Gasoline, Diesel Fuel from Coal			40.00-60.00
Ethanol from Sugarcane			25.00-45.00
Methanol from Natural Gas /e			25.00-45.00
Gasoline from Methanol			40.00-60.00
Shale Oil /f			25.00-35.00
Renewable Energy			
Firewood			8.00-20.00
Charcoal			30.00-80.00
Dung Cakes (India)			5.00-10.00
Solar Heat			50.00-90.00
Geothermal Heat			9.00-11.00
Electric power (at 2.4¢ to 10¢ per kWh) /g			40.00-166.00

a/ Posted prices from Platts Oilgram, June 6, 1980.
b/ Freight rates computed on basis of 60,000 ton tanker on Persian Gulf-Far East route, from Platts Oilgram June 9, 1980. White products (diesel and gasoline): clean tanker rate. Crude oil and Heavy fuel oil : dirty tanker rate.
c/ Natural gas price range derived from information on Bank projects and studies in Bangladesh, Pakistan and Thailand.
d/ Assumes production from fuel oil produced in local refinery from indigenous crude oil.
e/ Based on a gas price range of US$0.40-$1.50 per Mcf equivalent to US$2.27-$8.5 per boe.
f/ Based on Shell Group and Bechtel Corp. estimates with adjustment for inflation.
g/ Cost of electricity used in an electric heating device such as a cooking stove.

Sources: World Bank staff estimates except where noted.

ANNEX III: DEVELOPING COUNTRIES WITH POTENTIAL FOR NATURAL GAS PRODUCTION

AFRICA	LATIN AMERICA	ASIA
Algeria	Argentina	Afghanistan
Angola	Bolivia	Bahrein
Benin	Brazil	Bangladesh
Cameroon	Chile	Brunei
Chad	Colombia	Burma
Congo	Ecuador	China
Egypt	Guatemala	India
Ghana	Mexico	Indonesia
Ivory Coast	Peru	Malaysia
Madagascar	Trinidad and Tobago	Oman
Morocco		Pakistan
Niger		Papua New Guinea
Nigeria		Philippines
Rwanda		Syrian Arab Republic
Senegal		Thailand
Sudan		Turkey
Tanzania		Viet Nam
Tunisia		Yugoslavia
Zaire		

Source: Bureau d'Etudes Industrielles et de Coopération de l'Institut Francais du Pétrole.

H

International Bank for Reconstruction and Development

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R80-208

FROM: Vice President and Secretary

July 15, 1980

BRANDT COMMISSION RECOMMENDATION NO. 10 CONCERNING THE USE OF THE WORLD BANK'S GUARANTEE TO IMPROVE ACCESS OF DEVELOPING COUNTRIES TO CAPITAL MARKETS

As referred to in the President's memorandum of February 22, 1980 (SecM80-128), attached hereto is a memorandum dealing with the Brandt Commission Recommendation No. 10 concerning the use of the World Bank's guarantee to improve access of developing countries to capital markets.

Questions on this document may be referred to Mr. Baneth (X75837).

Distribution:

Executive Directors and Alternates
President
President's Council
Vice Presidents, IFC
Directors and Department Heads, Bank and IFC

THE WORLD BANK
Washington, D.C. 20433
U.S.A.

Office of the President

July 15, 1980

MEMORANDUM TO THE EXECUTIVE DIRECTORS

Subject: Brandt Commission's Recommendation Concerning the Use of the World Bank's Guarantee to Improve Access of Developing Countries to Capital Markets

Recommendation: "The World Bank and other international financial institutions should provide guarantees and play their part in ensuring a continued flow of commercial funds." 1/

1. The Commission feels that the economic environment in the coming years will be one in which the international capital markets might not, in the absence of intermediation by some public institutions, finance an adequate proportion of the very large capital requirements of the developing countries. The use of the World Bank's guarantee authority is seen as one form that such intermediation could take. This paper discusses, within the framework of the Bank's Articles of Agreement, the feasibility of using the guarantee authority, and the likely effects on the borrowing countries and on the World Bank.

Legal Authority

2. There are no legal barriers to the use of the Bank's guarantee authority; in fact, the Bank's Articles of Agreement treat guarantees as the primary form of development assistance and direct lending as an alternative to it (Article I). This is because, when the Bank was established, its European members required both capital for reconstruction and assistance in re-entering the capital markets. The Bank's guarantee was seen as a source of support facilitating the re-entry.

3. The Bank's Articles of Agreement treat guarantees as being similar to loans in their financial and other implications. In particular, the Articles stipulate that the sum of loans and guarantees by the Bank cannot exceed its capital plus retained earnings (Article III, Section 3). The Bank

1/ Willy Brandt and others, North-South: A Program for Survival, London: Pan Books, 1980, p. 275.

must meet the same conditions when it guarantees a developing country's obligations as it must when it extends a direct loan. The eligibility criteria for loans and Bank guarantees are almost the same (Article III, Section 4). These criteria are: (a) loans and guarantees can be issued only to member governments or with their guarantee; (b) both loans and guarantees have to be for a specific project, except in special circumstances (Article III, Section 4(vii)); (c) in both cases the appraisal and supervision of the project and the assessment of the borrower's creditworthiness are required (Article III, Section 4(iii)); and (d) for both loans and guarantees, the Bank must ensure that the amounts borrowed will be used only for the purposes for which the loan was granted (Article III, Section 5).

4. There are only some minor differences between the Articles' requirements for guarantees and loans. These are: (a) the Bank is required to control the disbursements only for direct loans and not for a loan it guarantees (Article III, Section 5); (b) the restrictions on loans extended for local currency expenditures (Article III, Section 3) are applicable only to direct loans and not to guarantees; (c) the Bank can guarantee loans only with the approval of the member countries in whose markets loans are raised and in whose currency they are denominated, and only if those members agree to the unrestricted conversion of the funds involved into the currency of any other member country (Article IV, Section 1); whereas these conditions have already been met in case of the Bank's resources available for direct lending.

5. The Articles do not impose any limit on the scope of the guarantee. This means the Bank can give either a full or a partial guarantee 1/ as long as all other terms and conditions (which are the same for a full or a partial guarantee) of the Articles are met. The amount of reduction in the Bank's commitment authority would depend upon what elements of the loan were guaranteed. If the Bank were to guarantee only the principal of a loan, the commitment authority would be reduced by that amount. If the Bank were to guarantee principal and interest only, Article IV, Section 5(c) would be relevant:

> "Guarantees by the Bank shall provide that the Bank may terminate its liability with respect to interest if, upon default by the borrower and by the guarantor, if any, the Bank offers to purchase, at par and interest accrued to a date designated in the offer, the bonds or other obligations guaranteed."

1/ See below.

The Bank's maximum liability under such a provision in its guarantee would be the principal amount plus the amount of interest that would accrue between the date of the last interest payment and the date the Bank purchased the obligations involved.

6. The Articles also specify that: "In guaranteeing a loan made by other investors, the Bank receives suitable compensation for its risk" (Article III, Section 4(vi)). "In guaranteeing a loan, the Bank shall charge a guarantee commission payable periodically on the amount of the loan outstanding at a rate determined by the Bank" (Article IV, Section 5(a)).

Historical Experience

7. The Bank has not directly used its guarantee authority, because it was felt that direct lending was more appropriate to the needs of its members. This was so even when the Bank's major borrowers were the more developed countries, and even when the statutory limits on Bank lending were so remote as to be disregarded in practice. Borrowers have preferred direct loans from the Bank to Bank-guaranteed loans from some other source, because the latter would be provided on harder terms, and in addition, the borrowers would have had to pay a guarantee commission.

8. The Bank has, however, used its guarantee authority indirectly, that is, by first making a direct loan and then selling that loan or a part of it to private investors with a guarantee (see Annex). This first occurred in 1948 when the Bank, with its guarantee, placed a part of its shipping loan to the Netherlands with a group of banks in the United States. The last sale of a loan with the Bank's guarantee was made in 1956 (the total amount between 1948 and 1956 of such sales was $69 million). The guaranteed loan sales were abandoned because they did not add much to a borrowing country's creditworthiness nor provide a cost-effective means of raising funds for them, as compared with direct borrowing from the Bank. Nor did they add to the overall resources that could be mobilized by the Bank, as the guaranteed principal amounts remained a charge against the Bank's overall lending authority until their repayment, in exactly the same way as if they had not been sold.

Effects on Borrowers

9. A borrower would find it advantageous to borrow under a World Bank guarantee if this:

-- increased the inflow of funds over and above that which could be achieved by direct borrowing from the Bank;

-- improved the borrower's market standing;

-- reduced the cost of funds; or

-- improved his cash flow position by lengthening the maturity of his borrowing.

These effects are examined below. The discussion is at first limited to the use of full guarantees.

(i) Additionality

10. All financial institutions must take into account contingent liabilities born out of guarantees. In the case of the Bank, as noted above, the Articles of Agreement specify that, from the point of view of its relations to total capital, guarantees should be treated in a way identical to the treatment of loans. This relationship would presumably prevail even if the rules governing the relationship of loans to capital were themselves changed. Therefore, whatever the Bank's lending authority, no additional capital inflows would result directly from the substitution of full guarantees to direct lending. In fact, the use of guarantees might even cause the Bank's lending authority to be used up more quickly, because the limitations established by the Articles of Agreement apply to disbursements when the Bank lends directly, but to commitments when the Bank offers guarantees.

11. Additionality may also result if, somehow, the sale of fully guaranteed loans gradually helped borrowers to establish a certain "market standing", and to introduce unguaranteed borrowings into the same markets. This possibility is examined in the following section.

(ii) Market Standing

12. It is sometimes argued that borrowing private funds under World Bank guarantees would help certain countries to improve their standing in international capital markets, so that they could issue their own unguaranteed obligations in the future.

13. It is difficult to find evidence of situations where a third party guarantee permanently enhanced the market standing of the recipient. The Bank's own (admittedly limited) experience with resales of loans with guarantees gives no indication that issuing full IBRD guarantees for a borrower's private market obligations materially assisted in improving the borrower's credit rating. This was an important factor in the decision to discontinue

the practice of guaranteed loan sales. Conversely, there is considerable evidence that the best way to establish a credit rating and to obtain improved access to more desirable sources of finance is by first borrowing from relatively hard sources and maintaining an impeccable debt service record. Thus, guaranteed export credits have often preluded syndicated Eurocredit borrowings; and such loans, in turn, have helped to introduce developing countries to the floating rate note and bond markets.

14. If the Bank were to offer guarantees, the creditors are likely to scrutinize mostly the creditworthiness of the guarantor (i.e., the Bank), rather than that of the issuer, because this would save them the cost and trouble of detailed long-term country economic analyses of a large number of widely varying and complex economies. Thus the process of exposing the borrower directly to the investor and promoting familiarization through successive in-depth creditworthiness evaluations, ultimately making it possible to issue unguaranteed obligations, is not likely to be much advanced.

(iii) Cost of Funds

15. Private bank loans are provided at higher interest cost and shorter terms than World Bank loans. This would still be the case if a guarantee improved the terms of such loans, to the point of making them comparable to those obtained by prime industrial country borrowers. This does not mean that the terms of the guaranteed loan would not be better than those of an unguaranteed loan; however, even this gain would be small under present market conditions for a wide array of borrowers, as the differentiation between high- and low-ranked borrowers (through spreads over LIBOR and management fees) has tended to be small. IBRD guaranteed bond issues would have to carry terms and offer yields more onerous than those of the Bank's own bond issues. This has been invariably the case even for the Government-guaranteed issues of such integral emanations of national states as the FHA in the US, or the SNCF in France. Moreover, even if a developing country did obtain the same maturity as the IBRD does on its borrowing, it would not be as well off as if it borrowed directly from the Bank, because the World Bank performs term intermediation, i.e., it lends longer than it borrows.

16. Finally, the IBRD is obligated (see supra, para 3) to subject guarantees to the same appraisal and supervision processes as direct loans. The costs of these would have to be recovered through the guarantee commission, to be charged in accordance with the Bank's Articles. One cannot yet precisely estimate the costs involved or the commission to be charged; but there are strong a priori reasons for such a commission to be not less than the .5% per annum spread between the Bank's borrowing and lending

rates paid by the Bank's direct borrowers. These guarantee commissions would further augment the difference between the cost of direct loans and the cost of loans guaranteed by the Bank.

Partial Guarantees

17. The foregoing discussion indicates that the use of full guarantees is not likely to provide much significant benefit to borrowers in terms of additional capital flows, cost of funds, length of maturities, or market standing. However, it is possible that in some cases the use of partial guarantees might be appropriate. 1/ A partial or limited guarantee means one of the following: (a) a guarantee of interest payments only; (b) a guarantee of principal only; or (c) a guarantee of principal or interest or of both only for some years out of the total maturity of a loan.

18. A partial guarantee can be put into effect in a number of ways. The most important could be the guaranteeing of a fixed amount of the principal. For the borrower and the lender this would have the advantage that, as the principal was increasingly paid off, a growing proportion of the outstanding principal amount would be covered by the guarantee. This would help alleviate some of the lender's concern, because later maturities are generally viewed as being riskier than earlier ones. The same effect could be obtained by guaranteeing the principal repayments of the last X years of the loan.

19. The impact of such guarantees on the Bank's finances should be compared with a loan with a correspondingly long grace period. The Bank does not normally make loans with very extended grace periods. If it were nevertheless found feasible to guarantee such later maturities, the corresponding guarantee commission would have to be higher than earlier indicated (para. 16). Such partial guarantees may be particularly useful to countries seeking to establish themselves on bond markets. A partial guarantee, covering, say, the outer maturities of a bond issue, may have a multiplier effect and enable the borrower to secure a larger total amount under acceptable conditions. There is no evidence yet as to how significant the multiplier effect of a partial Bank guarantee would be; the value of the guarantee tool could only be established and measured if it were put to use on a significant scale.

1/ Article IV, Section 1 "(a) The Bank may make or facilitate loans which satisfy the general conditions of Article II in any of the following ways: .....(iii) By guaranteeing in whole or in part loans made by private investors through the usual investment channels."

Alternatives to Bank Guarantees

20. From time to time, the Bank has considered the advantages of accepting closely binding cross-default clauses, as a means of mobilizing additional cofinancing for its borrowers. These would not involve financial obligations by the Bank, but would obligate it to apply specific remedies in case specified events of default affected the borrower's obligations to the co-lender. It is the Bank's policy not to accept such binding cross-default clauses, because it does not want to give up its freedom of decision concerning the application of its remedies in the event of actual or alleged default by a borrower. If the Bank were to extend guarantees to loans by third party lenders, its freedom of decision would be even more severely curtailed. It is therefore desirable to examine the possibility of using alternative means for facilitating the entry of selected borrowers into capital markets, and for helping them to mobilize a multiple of the resources committed by the Bank.

21. The resale of loans specifically designed for that purpose may achieve the resource-mobilizing impact of partial guarantees, without limiting the Bank's freedom of action in case of a subsequent dispute between the lender and the borrower. A partial guarantee such as the one described in the preceding section, i.e., limited to the later maturities of a private loan, would be very similar to a direct Bank loan, of which the early maturities are resold without the Bank's guarantee. Such a technique may be even more helpful to establishing the borrower's creditworthiness and introducing it to private lenders, because the Bank would normally locate such lenders directly, and could also perform certain regular services: for instance, the Bank has usually acted as billing agent on behalf of the purchasers of its loans. Of course, in the case of guaranteed loans, the financial and other terms and conditions of the direct loan agreement itself are closely adapted to the requirements of the lender, which may be quite different from those of the Bank. For a loan to be saleable, it may be desirable to design its terms and conditions at the outset in ways likely to be attractive to other lenders.

22. The Bank has made minimal use of loan sales in the past. They exceeded $100 million only in FY70 ($195 million), in FY77 ($165 million) and in FY78 ($162 million). This was because the cost to the Bank of funds obtained through such sales is normally higher than the cost of direct borrowing by the Bank. That is likely to remain the case in future. However, if a borrower must develop its access to funds other than the Bank, and limit the use it makes of the Bank's overall lending authority, the combination of direct financing of some maturities with the resale of others may be as advantageous to the borrower as the extension of partial guarantees by the Bank.

Conclusion

23. Guarantees affect the Bank's lending authority in the same way as loans disbursed and outstanding. Under foreseeable circumstances, there would be little benefit to the Bank or to its borrowers if the Bank were to fully guarantee loans by third parties. There is more justification for the use of partial guarantees, which might sometimes help borrowers to mobilize funds larger than the guarantee extended by the Bank or to introduce them to new lenders or preferred loan instruments. However, the use of the technique also involves risks for the Bank, by reducing its freedom of action. The possibility of achieving the same aims by using other techniques, in particular loan sales without guarantee, and cofinancing, should be carefully considered in each case.

24. If the use of such techniques is found to be not feasible or not beneficial, and if borrowers so request, the Bank is prepared to extend partial or full guarantees to certain loans. 1/ This would be done on the understanding that such guarantees would substitute for the same amount of direct lending to the borrower.

Robert S. McNamara

1/ The issue of guarantees was earlier considered in a staff memorandum, dated July 29, 1976 on "Use of the IBRD's Guarantee Authority", (Development Committee DC/WG/CM/76-7 dated August 4, 1976.) Subsequently, the Development Committee's Working Group on Access to Capital Markets noted (DC/WG/CM/77-4 dated August 1, 1977), that "The World Bank, in the light of the Committee's discussion in April, is now prepared to consider requests from member countries for partial guarantees of their bond issues. The initiative would now, therefore, seem to lie with individual "threshold" countries." No such request has yet been received by the Bank from any member country.

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ANNEX

Sales of IBRD Loans with Guarantee

Borrower	Loan No.	Years when sold	Amount ($m)
Belgium	14	1949	16.1
Brazil	11	1954-55	0.8
Chile	5	1955	0.1
	6	1951-53	1.7
	49	1954-56	0.6
Colombia	18	1952-53	2.0
	38	1953	0.1
	39	1952-53	0.2
	43	1952-53	0.8
	54	1953	0.1
El Salvador	22	1953	1.0
Finland	16	1952	0.7
France	1	1952	5.0
India	17	1952-53	4.8
	19	1952-53	2.6
	23	1956	1.0
Luxembourg	4	1955	0.2
Mexico	12	1952-56	2.2
	24	1952-53	0.6
	56	1953-56	1.3
	103	1956	1.6
Netherlands	2	1952-54	5.8
	7	1948	12.0
	15	1952	0.2
Nicaragua	44	1953	a/
	45	1953	a/
	52	1953	a/
Paraguay	55	1953	0.1
Pakistan	60	1952-53	0.7
Peru	57	1953-55	0.6
	67	1953-55	0.4
	98	1954-55	0.1
South Africa	41	1953-56	2.5
Thailand	35	1953	0.2
	36	1956	0.8
Turkey	27	1953	0.1
Uruguay	30	1953-56	2.0
		TOTAL	69.0

a/ Less than $50,000.