The Energy Transition in Developing Countries

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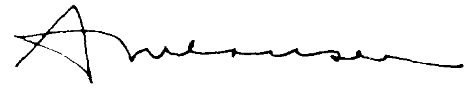
Foreword

The developing countries are in a period of adjustment to higher world energy prices and increasingly widespread shortages of fuelwood and other traditional fuels. The recent decline in international energy prices and their short-term unpredictibility do not reduce the need to continue planning on the premise of increased energy prices in the longer term. Accelerating domestic production of energy and programs to use energy more efficiently are equally essential features of this transition and will require both increasing financial commitments and policy and institutional changes. A major increase in the allocation of investible funds to the sector will be needed, both for exploration and development of domestic resources and for the management of energy demand. The report estimates that, over the next decade, the developing countries will need to invest about $130 billion a year in the energy sector, about half of it in foreign exchange. This, in turn will require a major increase over the current level of external funds flowing to the energy sector in developing countries and underlines the urgency of expanding these flows from all sources—private and public, equity and debt. Concomitant efforts to mobilize additional local resources within the developing countries through appropriate energy pricing and other measures will be equally important. The success of both these efforts will depend in many countries on a stronger management capability and institutional framework for the energy sector.

This report presents an analysis of issues for the sector, on the basis of experience gained by the World Bank and its member countries in the energy sector in the three years since the publication of *Energy in the Developing Countries*, the Bank's last comprehensive report on the subject. Since 1979, the Bank's activities in the sector have expanded substantially. Energy lending has more than doubled, including a nearly fourfold increase in the financing of oil and gas projects. In parallel, the Bank worked with over 30 countries to assess the major energy problems facing them under a joint program with the United Nations Development Programme.

The analysis in this report indicates that the Bank should continue to accord a high priority to the energy sector in its overall lending program. The World Bank has an important contribution to make in assisting developing countries overcome the resource and managerial constraints in the energy sector. Financing by the Bank plays an important catalytic role by attracting private sector investors and lenders to participate in high priority, economically sound, and financially attractive projects. At the same time, the report illustrates the role the Bank plays in its borrowing countries in the areas of policy advice, institutional strengthening, technology transfer, and improved project selection, design, and implementation.

This report was prepared by Masood Ahmed with Helena Ribe and with a team of Bank staff members under the direction of D.C. Rao, Assistant Director of the Bank's Energy Department.



A. W. CLAUSEN
President, The World Bank

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Abbreviations and Definitions

boe	Barrel of oil equivalent
bdoe	Barrel per day of oil equivalent
tce	Metric ton of coal equivalent
toe	Metric ton of oil equivalent
tpy	Metric ton per year
Btu	British thermal unit
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
MMCFD	Million cubic feet per day
tcf	Trillion cubic feet

IBRD means the International Bank for Reconstruction and Development.

IDA means the International Development Association, an affiliate of the World Bank, which provides assistance on concessional terms.

IFC means the International Finance Corporation, an affiliate of the World Bank, which invests in commercial enterprises in developing countries.

The World Bank refers to the combination of the IBRD and IDA operating as a single institution, and often referred to simply as "the Bank."

ODA means official development assistance, sometimes referred to as foreign aid.

UNDP means United Nations Development Programme.

Years used in this report are World Bank fiscal years when referring to data relating to the operations of the IBRD or IDA, and run from July to June of the calendar year. Fiscal 1983 ended on June 30, 1983.

GDP means gross domestic product.

GNP means gross national product.

Economic and energy terms are defined in the technical notes to the Statistical Annex of this volume.

Billion is 1,000 million.

Growth rates are in real terms unless otherwise stated.

Dollars are United States dollars unless otherwise specified. All prices and costs in this report are expressed in U.S. dollars.

Symbols used in the tables are as follows:

.. Not available

– Zero or negligible

Glossary

API gravity. This is a convenient method of expressing the specific gravity of crude oil and petroleum products used by the petroleum industry. The relationship between API and specific gravity is:

$$\text{API gravity} = \frac{141.5}{\text{Specific Gravity at } 60^\circ \text{ F}} - 131.5$$

Biomass fuels. Combustible or fermentable material of vegetable origin, for example, wood, charcoal, corn cobs, cotton stalks, rice husks, and dung cakes.

Catalytic reforming. Catalytic (or "Cat") reforming is one of the most common petroleum refining processes used to produce high octane blending components for motor gasoline. This process takes naphtha (a straight run light distillate product) and changes the chemical composition of the feedstock in the presence of a catalyst to make the product more suitable for use as engine fuel.

CNG. Compressed natural gas.

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

Conventional energy. Energy sources which have hitherto provided the bulk of the requirements for modern industrial society. These include 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 geothermal, 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.

Cracking. A refining process in which the feedstock is subjected to high temperature for a limited time with the objective of increasing the yield of lighter products. In the process, the heavier component's molecules are broken down into smaller (lighter) molecules. The process is carried out through the action of temperature and pressure (thermal cracking), or in the presence of a catalytic substance (catalytic cracking) which promotes selectively the required reactions and end products.

Development well. A well drilled within the known or proved productive area of an oilfield, after the field's existence has been confirmed as needed to appropriately produce gas, oil, or both.

Diesel oil. A middle distillate refinery product used mainly in internal combustion engines, also known as diesel engines.

Distillation. The refining process of separating crude oil components by heating and subsequently condensing the fractions by cooling. First to boil off would be the liquefied petroleum gas, then gasoline, kerosene, gas oil, and possibly light lube oil, until a heavier residue is left. Distillation below atmospheric pressure (vacuum distillation) is applied to the residue of the atmospheric distillation process. The reduced pressure has the effect of lowering the boiling point of heavy gas oil and enables it to be separated from the residues.

Dry well. A well that is not expected to produce hydrocarbons in sufficient quantity to make its development into a producing well a worthwhile proposition.

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.

Exploratory well. The term refers to two different categories of wells, depending on the objective of the well. It could either be to learn the geologic series (stratigraphic well) or to eventually find oil and gas. In both cases, core samples are taken in the course of drilling.

Gasoline. A light petroleum distillate that conforms to the specifications required of fuel in internal combustion engines. Premium automobile gasoline has a Research Octane Number (RON) of 93 and above.

Geothermal power generation. The use of underground natural heat sources for commercial energy. This is usually superheated water deep in the earth that is used to generate steam to power turboelectric generators.

Heavy fuel oil. A residual petroleum product with a high sulfur content, usually in the range of 2.2 to 3.7 percent. Heavy fuel oil is primarily used for power generation and industrial boilers.

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

Hydrocracking. This petroleum refining process cracks heavy petroleum fractions under very high pressure and in the presence of hydrogen to produce higher quality, lighter products. Compared to thermal or catalytic cracking processes, higher yields of kerosene and gas oil result from this procedure.

Hydrofining. In this petroleum refining process, sulfur is removed from distillates. Desulfurization is necessary to meet limits of sulfur content in gasoline, middle distillates, and fuel oil. These limits are imposed mainly because of the corrosion and contamination of metals caused by sulfur and by air pollution control laws. This is a British Petroleum trademark for hydrotreating.

Hydrotreating. In this process, diesel oil or gas oil and lighter products are desulfurized by adding hydrogen in the presence of a catalyst. In hydrotreating processes, practically all sulfur compounds are turned into hydrogen sulfide.

Kerosene. A refined petroleum product between gasoline and gas/diesel oil in volatility and free of gasoline and heavy hydrocarbons such as gas oil and lubricating oil. It is used as an illuminant in cooking and heating stoves, and as a fuel in certain types of spark ignition engines such as those used for agricultural tractors and stationary engines. Jet fuels are part of this fraction.

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.

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.

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

vegetable origin are regarded as renewable; mineral fuels and nuclear power are not.

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

Solid fuels. Forms of solid energy are coal and lignite. All primary solid fuels are converted from a volume or mass basis to a common ton of oil equivalent using specific national conversion factors (see Table of Conversion Factors).

Spud. To break ground with a drilling rig at the start of well drilling operations.

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.

Thermal operations/thermal cracking. This petroleum refining process is effected solely by the action of temperature and pressure and is characterized by a high yield of coke and light product.

Thermal power generation. A power station which uses oil, gas, or coal to generate thermal energy usually in the form of steam which is used to drive electric generators. However, the term also includes diesel engines and gas turbines.

Traditional or noncommercial energy. Those energy forms generally used in "traditional" or preindustrial 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. These energy forms are sometimes also referred to as noncommercial energy, even though wood fuels are often traded.

Ultimate recovery 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.

Well. A borehole sunk into the ground for the purpose of obtaining oil or gas from an underground source, or for introducing water or gas under pressure into an underground formation.

Wildcat well. An exploratory well drilled for oil and gas on a geologic feature not yet proven to be productive, in an unproven territory, or in a zone that has never produced or is not known to be productive in the general area.

Classification of Countries

Developing Countries

Low income

Oil importers

Afghanistan
Bangladesh
Benin
Bhutan
Burma
Burundi
Cape Verde
Central African Republic
Chad
Equatorial Guinea
Ethiopia
Fiji
Ghana
Guinea
Guinea-Bissau
Haiti
India
Kampuchea, Democratic
Lao PDR
Madagascar
Malawi
Mali
Mozambique
Nepal
Niger
Pakistan
Rwanda
Sao Tome and Principe
Sierra Leone
Somalia
Sri Lanka
Sudan
Tanzania
Togo
Uganda
Upper Volta
Viet Nam
Zaire

Oil exporters

China

Middle income

Oil importers

Argentina
Barbados
Bolivia
Botswana
Brazil
Cameroon
Chile
Colombia
Costa Rica
Cuba
Dominican Republic
El Salvador
Greece
Guatemala
Guyana
Honduras
Hong Kong
Israel
Ivory Coast
Jamaica
Jordan
Kenya
Korea, PDR
Korea, Republic of
Lebanon
Lesotho
Liberia
Mauritania
Mongolia
Morocco
Nicaragua
Panama
Papua New Guinea
Paraguay
Philippines
Portugal
Senegal
Singapore
Thailand
Turkey
Uruguay
Yemen Arab Rep.
Yemen, PDR
Yugoslavia
Zambia
Zimbabwe

Oil exporters

Algeria
Angola
Congo, PR
Ecuador
Egypt
Gabon
Indonesia
Iran
Iraq
Malaysia
Mexico
Nigeria
Peru
Syrian Arab Republic
Trinidad and Tobago
Tunisia
Venezuela

Industrial Market Economies

Australia	Japan
Austria	Luxembourg
Belgium	Netherlands
Canada	New Zealand
Denmark	Norway
Finland	Spain
France	Sweden
Germany, Federal Republic of	Switzerland
Iceland	United Kingdom
Ireland	United States
Italy	

High Income Oil Exporters

Bahrain	Oman
Brunei	Qatar
Kuwait	Saudi Arabia
Libya	United Arab Emirates

Centrally Planned Economies

Albania	Hungary
Bulgaria	Poland
Czechoslovakia	Romania
German Democratic Republic	USSR

Note: This table is based on the classification used in the *World Development Report 1983*. The table does not show all countries with less than one million population and without production (or prospects of future production) of oil, gas, and coal.

Conversion Factors: Approximate Calorific Equivalents

One ton of oil equivalent (toe) equals approximately:

Heat units

10.2×10^6	kilocalories
40.5×10^6	BTUs
$42{,}700 \times 10^6$	joules

Electricity

4.0×10^3 kilowatt-hours of primary electricity at thermal replacement value based on efficiency of about 34 percent in thermal electricity generation.

Natural gas

40.47×10^3 cubic feet.

Solid fuels

1.46 tons of standard coal. Actual calorific values of solid fuels are the same as those given by the United Nations, *World Energy Supplies 1980,* with the following exceptions: Argentina, 1.82 tons of coal; Brazil, 2.42 tons of coal; Egypt, 1.46 tons of coal; Indonesia, 1.96 tons of coal; Mexico, 2.16 tons of coal; Philippines, 1.81 tons of coal; Thailand, 4.03 tons of lignite; and Turkey, 1.46 tons of coal, or 5.18 tons of lignite.

Summary

The world entered an era of higher energy costs almost a decade ago. The transition was an abrupt one and most developing countries have still not adjusted their energy consumption and production patterns fully to reflect the higher costs of energy, and particularly imported oil whose price has increased fivefold in real terms since 1973. This adjustment process entails a wide range of actions: increasing the efficiency of energy use through rational pricing and other demand management measures; undertaking a vastly expanded and more diversified program of investments to develop indigenous energy resources where these are cheaper than imported energy; reorienting industrial, agricultural, and transport development strategies to take account of the higher costs of energy; and strengthening the institutional and management capability in the energy sector to carry out these tasks effectively.

The Global Setting

The transition process is particularly difficult for the oil importing developing countries. They must raise the resources for an expanded program of energy investments to reduce their dependence on oil imports while, at the same time, continuing to pay for these imports until the investments mature. The issues are similar in several oil exporting developing countries. They, too, must restrain the growth of oil consumption and promote the utilization of other energy resources in order to maintain the flow of oil export revenues.

Developing countries account for one-fourth of the world's production and one-fifth of the world's consumption of commercial energy. Their shares of both consumption and production are rising rapidly. By 1995, they will account for one-third of the world's production of commercial energy and one-fourth of the world's consumption. Thus, as a group, the developing countries will continue to be net exporters of commercial energy to the rest of the world. Underlying these figures is a combination of slower commercial energy consumption and accelerated indigenous energy production in the developing countries compared with the past. Between 1980 and 1995, the growth of gross domestic product (GDP) in the developing countries may be slightly lower than in the 1970s (4.8 percent a year *versus* 5.1 percent a year), but the rate of growth in their commercial energy consumption is expected to fall appreciably, from 5.9 percent a year in the 1970s to 4.5 percent a year in 1980–95. In contrast, the growth in commercial energy production in the developing countries is projected to accelerate to 4.2 percent a year in 1980–95 compared with 3.6 percent a year in the 1970s. This pattern is repeated in the oil importing developing countries; as a result, they are able to reduce the growth in their net imports of oil from 6 percent a year in the 1970s to about 2 percent a year in 1980–95.

These projections are, of course, subject to many uncertainties and assume that developing countries will take strong action to improve the efficiency of their energy use and will be able to undertake the necessary investments to exploit economic opportunities for substituting imported oil by other cheaper energy sources—domestic or imported.

The urgency of these measures is not alleviated by the recent softening in international

oil prices. Although oil prices have dropped sharply over the past year, they remain considerably higher than the prices that prevailed only four years ago. Moreover, while the movement of oil prices remains unpredictable over the short term, most analysts agree that oil prices are likely to rise again in real terms during this decade. Energy strategy and investment planning decisions must be made on these expectations about price in the late 1980s and the 1990s. Hence, a temporary decline in the price of oil should not detract attention from the longer-term importance of reducing dependence on imported oil that is considerably more expensive than many available alternatives.

Increasing Energy Efficiency

Recent experience and analysis have confirmed that developing countries can improve the efficiency of energy use in virtually all sectors. This requires a wide range of measures, of which rational energy pricing has proved to be particularly important. A review of the current state of energy pricing shows that oil importing developing countries have, in most cases, already passed on the higher costs of imported energy to final consumers. But most oil exporters continue to price oil in their domestic markets below its opportunity cost. In both groups of countries, there are still imbalances in the relative price of petroleum products and substantial improvements need to be made to bring the price of domestically produced fuels (principally electricity, but also coal and gas) more in line with the opportunity costs of supply.

Experience has shown that appropriate pricing usually needs to be supplemented with other demand management measures such as promotional or educational efforts along with training and technical assistance. Effective demand management programs must be selective in their focus and employ specifically designed strategies to meet the needs of different sectors or user groups. For the larger energy users—such as large energy-intensive industrial plants, large public and private transport enterprises, and electric power utilities—direct government assistance and support may be necessary to identify and realize the substantial savings that can be achieved through better energy management, maintenance, and other low-cost improvements as well as through large investments in retrofitting and process change. For the smaller users in all sectors, the priority is to develop the relevant policies conducive to conservation as well as suitable institutions to provide them with the information, incentives, and know-how to improve their own energy efficiency.

Increasing Energy Supply

Developing countries can reduce energy costs significantly by investing in their indigenous energy resources. A review of the supply potential and market requirements in developing countries indicates that their production of commercial energy could rise from 1.7 billion tonnes of oil equivalent (toe) in 1980 to 3.1 billion toe in 1995. Approximately, 32 percent of this increase would be in the production of oil, 27 percent in coal, 22 percent in natural gas, and 19 percent in primary electricity (mainly hydro and nuclear power). Achieving such a sizable increase in energy output will require action on several fronts. First, most developing countries need to formulate clear strategies on how to use the several available means of accelerating the identification, evaluation, development, and marketing of each indigenous energy resource. Second, they must embark on a focused program of preinvestment work to minimize the possibility of expensive mistakes in large, complex energy investments. Third, there is a need to strengthen the management of the energy sector, both in national planning and policy formulation as well as in the capacity of individual energy enterprises to implement and operate projects of growing complexity. Finally, and most important, a massive effort is required to mobilize both domestic and external resources for financing investment.

Energy Investment

The Bank estimates that achieving the projected level of energy output in developing countries requires an average annual investment of about $130 billion (in 1982 dollars) over the next decade, or a doubling of the share of energy investments in GDP from about 2 to 3 percent of GDP during the late 1970s to an average of about 4 percent of GDP over the next decade. This is a major financing problem even allowing for a reallocation of resources from other sources, and it underlines the need for a greater effort to mobilize energy financing from all possible sources; these include both official and commercial financing, debt, and equity. This effort will be necessary and justified under a wide range of plausible scenarios concerning future oil prices. The bulk of the projected investments would still be advantageous to developing countries even if the price of oil settles at a relatively low level (say $25 per barrel in 1983 dollars). Thus, the $130 billion of investment requirements constitutes a reasonable planning assumption.

About half of the projected investment requirements, that is $64 billion per year, is in foreign exchange. This foreign exchange requirement compares with an estimate of $25 billion for the actual flow in 1982 of external capital to finance energy investment in developing countries.[1] Hence, these flows will need to expand by about 15 percent a year in real terms to meet developing countries' foreign exchange financing requirements over the next decade.

Over half of the foreign exchange required for energy investments is in the middle income oil exporting countries, which are generally in a better position to raise commercial loans and attract direct investments. However, financing for the low income countries is much more constrained; they are estimated to require 16 percent of the foreign exchange flowing to all developing countries, but receive only 9 percent of publicly guaranteed external credits and an even smaller share of other external capital. For these low income countries in particular, it is essential that greater support from official sources be provided, particularly in the form of concessional credit consistent with their overall debt servicing capacity.

A sectoral analysis of financing requirements and of past external flows highlights the need for a quantum increase over current levels in the external capital flows for oil and gas investments. This problem is particularly severe for the oil importing developing countries whose petroleum investment requirements are rising sharply and where the prospects for direct equity investments or for nonrecourse project financing are much more limited. Financing from all sources, both official and commercial, will need to be increased if the financing gap in this sector is to be filled.

The mobilization of adequate local resources for energy investment will be equally important. Appropriate pricing policies will be critical to ensure a reasonable degree of internal cash generation to meet domestic investment requirements. Past reliance on budgetary transfers to the energy sector has had adverse effects on the autonomy and operational capacity of energy enterprises in many developing countries. Improving domestic resource mobilization is vital given the likely scarcity of external capital which makes it unrealistic to rely on external financing of domestic costs, except in the most unusual circumstances. To a large extent, the mobilization of adequate domestic resources will be attained only if the prices of electricity, coal, oil, and gas fully reflect economic costs of supply. Further, augmenting operational efficiency and strengthening the financial structure and procedures of energy enterprises should also make a substantial contribution to resource mobilization.

Energy Sector Strategies

Making more efficient use of available financial resources requires the explicit formulation of a development strategy in the sector and a program for policy reform and institutional strengthening. Experience indicates that these issues are most effectively addressed for the energy sector as a whole, establishing relative investment priorities and pricing policies that take account of substitution opportunities among different fuels. Mobilizing domestic and external financing and developing a framework to focus the use of external technical assistance are also best handled at the sectoral level. However, a number of spe-

1. Based on available data on flows of publicly guaranteed debt in 1980 and making some allowances for the addition of nonguaranteed debt, direct private investments, and real growth in guaranteed debt from 1980 to 1982.

cific issues also need to be tackled in each energy subsector.

The *power* sector illustrates the need to improve strategic planning even in the most established energy subsector in developing countries. The increase in oil prices and the greater capital intensity of nonoil-based power generating capacity have increased the complexity of power system planning. There is also a greater need to improve plant operating efficiency and reduce transmission and distribution losses. These measures are particularly cost effective and significant not only because power is usually the largest item in the public investment programs of developing countries, but also because changing the mix of electricity generation will probably be the most potent means of achieving interfuel substitution in most developing countries. Between 1980 and 1995, oil-based electricity generation is projected to decline from 26 percent to 7 percent of total generation, with shares of coal- and gas-fired thermal, hydropower, and nuclear electricity all rising to offset this change.

A sharp acceleration in *oil* exploration and development is required, particularly in the oil importing developing countries. To achieve this, governments need to formulate clear and realistic petroleum development strategies which would define the contribution that could be made by various sources of technological know-how and finance. These sources include domestic and international private oil companies, commercial and official credit agencies, and the national oil company. Countries must identify acreage suitable for promotion to international oil companies and the measures needed to establish an attractive contractual and operating environment; to establish a national capacity to monitor and manage exploration activity in the country; and, where appropriate, to strengthen the ability of the national oil company to engage directly in petroleum exploration and development.

Natural gas resources exist in about 50 developing countries, including about 30 which are currently oil importers. However, there has been little systematic exploration specifically aimed at discovering natural gas. Even when gas discoveries have been made, development has been slow because of market considerations, lack of infrastructure, and the absence of a coherent gas development program. In general, the cost of gas production is lower and the potential domestic demand higher and more diversified than previously believed. However, the economics of gas use are highly site and project specific and the formulation of a national gas development strategy requires complex and difficult analysis. Thus, in parallel with efforts to explore and appraise gas reserves, an active effort is needed to promote the use of gas, to clarify pricing and related contractual arrangements, and to provide the necessary infrastructure to use this fuel. Few developing countries have either formulated such an integrated strategy for the exploration and utilization of gas, or developed an institutional capability for doing so.

In nearly all *coal* producing countries, recurrent constraints are the absence of a coherent strategy; poor coordination among coal production, infrastructure, and utilization projects; and an institutional framework which is characterized by limited managerial expertise and a range of bureaucratic obstacles. Similar problems also affect the planning and implementation of programs to import coal as a substitute for more expensive oil. Without major improvements in these areas, it is unlikely that many developing countries can take advantage of coal's substantial competitive advantage over oil.

Geothermal resources are widely distributed, but only nine developing countries have so far constructed geothermal power generation facilities. Several other countries have good geological prospects and a sizable potential market for geothermal electricity, but the development of this resource is limited by a lack of data and institutional drive. A carefully phased program of reconnaissance work, market surveys, geophysical surveys, and exploratory drilling is needed to realize the geothermal potential of these countries. However, several institutional issues, including pricing, will need to be addressed before such a program can be effectively implemented.

In all developing countries, a major effort will be needed to counter the overcutting of trees to provide *fuelwood* or charcoal. These fuels are the principal sources of energy for a large proportion of developing country households, including low-income families in urban areas. Recent studies have confirmed earlier evidence on the extent and severity of a growing fuelwood crisis in a large number of developing countries. The need to expand dramatically reforestation efforts and to improve the efficiency of wood use through better designed cookstoves and charcoal kilns is now widely recognized. However, even though recent experience has identified the constraints that need to be overcome, the mounting of effective large-scale programs of afforestation and improved cookstove dissemination has been slow and often ineffective. These constraints include an inadequate infrastructure and institutional capability, the difficulties of mobilizing strong local participation in tree planting programs, and the lack of appropriate technical packages for specific areas. It is also clear that greater emphasis should be placed on low-cost approaches to tree planting that are more closely attuned to people's perceived needs and better integrated with their agricultural pursuits. Moreover, many countries need to give higher priority to fuelwood and rural energy problems generally. Stronger international technical and financial assistance is also called for to help step up investment efforts and strengthen national institutions.

The recent anticipation that developing countries would be able to harness the enormous potential resources of *renewable energy* has not yet been fulfilled for two principal reasons. First, the development, adaptation, and application of certain technologies such as photovoltaics and biogas digesters, has proved more difficult, and their costs have not come down as quickly as was initially forecast. Second, the institutional and policy framework for assessment and commercialization of suitable technologies has been weak. Heightened national and international efforts in the areas of resource measurement; planning and marketing studies; research, development, and testing; and pilot and demonstration projects can all help materially to spread the use of the solar, biomass, wind, and other renewable technologies that are already commercially viable for many uses.

The World Bank's Energy Program

The principal objective of the World Bank's energy program is to assist developing countries to define and implement appropriate strategies to meet their urgent needs. The urgency and the magnitude of structural adjustments necessary in the energy transition imply much greater attention to policy and management issues, preinvestment studies to formulate better strategies for energy supply and utilization, and the mobilization of financing for the large investments required. The Bank has responded to these needs and attempted to function as a catalyst in promoting strategy formulation, policy reform and institutional strengthening, and in mobilizing the flow of technology and finance to implement effectively the changed investment priorities in developing countries. It has expanded and diversified its energy lending and is putting greater emphasis on providing advice and technical assistance to its borrowers.

Jointly with the United Nations Development Programme (UNDP), the Bank has launched the Energy Sector Assessment Program designed to provide a rapid evaluation of the main energy issues and options in 60 countries and to serve as a framework for multilateral and bilateral technical assistance in the sector. This program is being followed by an Energy Sector Management Program designed to provide a rapid and flexible response to governments who request technical or management assistance in implementing the strategy proposed in the energy assessments and in carrying out prefeasibility studies to identify priority energy projects.

The Bank is the single most important official source of external capital for energy development in the developing countries. Its energy lending (including credits from the International Development Association) has doubled from \$1.5 billion in fiscal 1979 to \$3.4 billion in fiscal 1982. Further, the Bank has made a special effort in the energy sector to mobilize additional external financing and promote opportunities for direct private investment. During fiscal 1979–82, the \$9.9 billion of Bank lending for energy was associated with another \$11.2 billion of cofinancing from other external sources.

In financing energy projects, the Bank has sought to build on its traditional strengths in assisting in project selection and implementation through better sector analysis, transfer of technology, and strengthening of institutions and sector management capacity. The Bank's approach to project financing has emphasized the review of sector objectives, priorities, and investment options. The dialogue with national policymakers covers a wide range of issues, such as demand management and pricing, interfuel substitution, investment planning, resource mobilization, and the respective roles of public and private agencies in the development of the sector. This work has made an important contribution in helping to define "energy" as an integrated sector in many developing countries.

In recognition of the developing countries' needs, the Bank has increased its involvement in petroleum, where its presence helps overcome the constraints impeding the acceleration of exploration and development activity. The Bank has helped countries in formulating a sound strategy which takes account of the need to offer international oil companies a contractual and operating environment that is attractive, stable, and consistent with the country's interest. This has involved the financing of data acquisition and technical assistance designed to accelerate the competitive offering of new acreage to the international petroleum industry on reasonable terms. The preliminary results of such exploration promotion projects have been encouraging. The Bank has also been ready to support the allocation of public resources to petroleum development when it is convinced that this is an appropriate feature of the country's optimal sectoral and national development strategy, as is the case when the priorities of the international petroleum industry do not match the priorities of the country.

While the need and the scope for increasing the scale of Bank involvement in the energy sector is clearly considerable, there is a definite resource constraint. The Bank's energy lending cannot exceed about 25 percent of its total lending without curtailing its lending for other high priority investments below acceptable levels. Applying this guideline, the Bank's energy lending during fiscal 1983–87 is unlikely to exceed approximately $4 billion a year on average (1983 dollars), growing in line with aggregate lending by the Bank. Despite the scarcity of resources, continuation of Bank involvement at this level is justified by the priority that the energy sector has in the overall adjustment process for many developing countries, by the complex and substantial adjustment that is urgently required within the energy sector in member countries, and by the very large volume of financing necessary to carry out this energy sector adjustment in all countries.

1. The Energy Outlook

The fivefold increase in international oil prices, in real terms, over the past decade has had profound effects on balance of payments and growth prospects in developing countries.[1] While the recent easing of the international oil market has temporarily reduced the burden of energy imports for many countries, the more fundamental challenge facing both industrialized and developing countries remains unchanged: managing the process of transition to an era of high-cost energy. This will entail heavy investments to develop sources of energy which are more economical than the import of oil; the management of energy demand through pricing and other measures to increase the energy efficiency of economic activity; and improved macroeconomic and sectoral management to cope with problems of resource mobilization, technology transfer, and coordination among energy enterprises and ministries.

Developing countries have made big strides in the adjustment process, particularly following the doubling of oil prices in 1979/80. However, progress has been uneven and much remains to be done to tap their potential energy resources and to maintain the momentum of economic development despite the higher costs of energy. The purpose of this report is to reexamine these strategic issues, mainly from a developing country perspective, in the light of the experience gained in recent years, and to reevaluate the financial and institutional constraints on the effective management of energy transition.[2] This analysis also provides a basis for reexamining the rationale for the World Bank's activities in the energy sector, which have expanded significantly in recent years (see Box 1.1).

The Global Setting

The recent slowdown in the growth of world energy consumption has led many to question whether the traditional relationship between energy consumption and economic growth has been permanently altered. It is clear that energy conservation measures and the price-induced fall in the consumption of energy-intensive goods and services have added significantly to the fall in energy demand attributable to the world economic slowdown. However, there is still no widespread agreement on the relative importance of these factors, or on how closely these recent trends will be reflected in the future relationship between energy consumption and economic growth. Moreover, the future pace of world economic growth is itself uncertain. Consequently, there is a wide range of opinion on future trends in the consumption of energy, particularly oil, and their implications for the price of oil. The projections of energy supply and demand in this report are also subject to these uncertainties and should not be interpreted as firm forecasts. The main objective of presenting these projections is to provide a plausible global framework for energy supply and demand in which to

1. Based on the weighted average official selling price (in 1982 dollars) of light crude oil (34°–34.9° API, marker crude) from members of the Organization of Petroleum Exporting Countries (OPEC) for the period 1972–83.

2. The last major report by the World Bank on this subject was *Energy in the Developing Countries*, August 1980.

Box 1.1. *The World Bank's Energy Program*

The World Bank's lending for energy projects has expanded rapidly in recent years, from \$1.1 billion in fiscal 1977 to \$3.4 billion in fiscal 1982. Of the total lending in fiscal 1982, \$700 million were highly concessional IDA credits to low income countries. As a proportion of the World Bank's total lending, energy's share was 14.8 percent during the period fiscal 1976–78, rising to 19.4 percent during fiscal 1979–81 and 25.8 percent in fiscal 1982.

A key feature of the larger energy lending by the World Bank has been diversification—adding, on an increasing scale, oil and gas exploration and development, other sources of energy, and energy conservation to the previous lending for power, coal, and pipelines. However, power still accounts for the largest share of the Bank's lending for energy in the developing countries.

The growth in lending for oil and gas has been most striking. Since the inception of this program in 1977, projects have been identified in over 50 countries and loans have been made for 44 projects in 36 countries, for a cumulative amount of about \$1.8 billion. Among these, 26 loans for about \$290 million were for predevelopment activities started since 1979, when lending for this purpose was approved. In fiscal 1983, the Bank is expected to lend about \$1 billion for oil and gas. A program to accelerate exploration and development of coal was formulated in 1979. Five projects have been approved since then and a further twelve are under preparation.

Following a systematic review of renewable energy needs and potential, the Bank has been building up a lending program that stresses fuelwood projects, selective support for alcohol programs, and the incorporation of technologies for using renewable energy as components in Bank projects, sometimes on a demonstration or pilot basis. The Bank recently began lending to upgrade the processing facilities in refineries to convert fuel oil into middle distillates and to support a wide range of activities to help increase the efficiency of energy use in developing countries.

Its program also supports the formulation and implementation of policies to foster rational energy development and to encourage the mobilization of the required resources, both human and financial. This is done through loans for projects, structural adjustment, and technical assistance, all of which are appraised in their sectoral and subsectoral context and help to support the rational selection of investment priorities, pricing and institutional reform, manpower development, and transfer of technology. It is also done by way of the UNDP/World Bank Programs of Energy Assessments and Energy Sector Management.

discuss policy and strategy issues as they affect developing countries. Moreover, it is important to note that while the actual energy consumption projections will change under alternative assumptions of economic growth, or relative energy prices, even relatively large changes in these parameters have virtually no effect on the report's conclusions and recommendations regarding energy policy and strategy in the developing countries.

World energy consumption is projected to grow at 2.3 percent a year during the 1980–95 period, or somewhat more slowly than the 3 percent annual growth rate of the 1970s (see Table 1.1). The future pattern of energy consumption is likely to differ markedly from that of the 1970s. Oil consumption, which was stagnant in 1982, is expected to grow by less than 1 percent a year during the next decade. While oil accounted for about 43 percent of the increase in global energy consumption between 1970 and 1980, it is projected to contribute only 10 percent of the increase during the 1980–95 period—largely because countries are developing and using other sources of energy that have now become economic. Among these other sources, the most significant change will be for primary electricity—mainly hydropower and nuclear power generation—whose share in global consumption is projected to rise from 9 percent in 1980 to 15 percent in 1995. Coal will contribute 36 percent of the increase in global consumption during 1980–95 compared with 20 percent during the previous decade, but its share of the total will not change significantly. The share of natural gas in global consumption will increase slightly to about 20 percent (see Figure 1.1).

A major assumption underlying the projections is that the current softening of oil prices will not cause any fundamental change in the long-run trend of rising oil prices. Oil prices will no doubt fluctuate in the future as supply and demand conditions change in the world oil market, but there is little likelihood that the decline in oil prices caused by the current overcapacity in oil production will last beyond the mid-1980s.

Table 1.1. *World Commercial Primary Energy Consumption, 1970–95*

	Million toe[a]			*Growth rate (percentage per year)*	
	1970	*1980*	*1995*	*1970–80*	*1980–95*
Oil	2,311	3,067	3,355	2.9	0.6
Coal	1,475	1,825	2,821	2.2	2.9
Natural gas	889	1,241	1,930	3.4	3.0
Primary electricity[b]	328	611	1,423	6.4	5.8
Total	5,003	6,744	9,529	3.0	2.3
	Percentage of total			*Percentage of increase*	
	1970	*1980*	*1995*	*1970–80*	*1980–95*
Oil	46.2	45.5	35.2	43.4	10.3
Coal	29.5	27.1	29.6	20.1	35.8
Natural gas	17.8	18.4	20.3	20.2	24.7
Primary electricity[b]	6.5	9.0	14.9	16.3	29.2
Total	100.0	100.0	100.0	100.0	100.0

Note: Energy consumption includes bunkers.

a. Toe = tons of oil equivalent.

b. Primary electricity comprises electricity generated from hydropower, nuclear energy, or geothermal resources. Throughout this report, primary electricity is converted into tons of oil equivalent (toe) at thermal replacement value, assuming an average conversion efficiency of about 34 percent.

Sources: United Nations J Series and World Bank estimates.

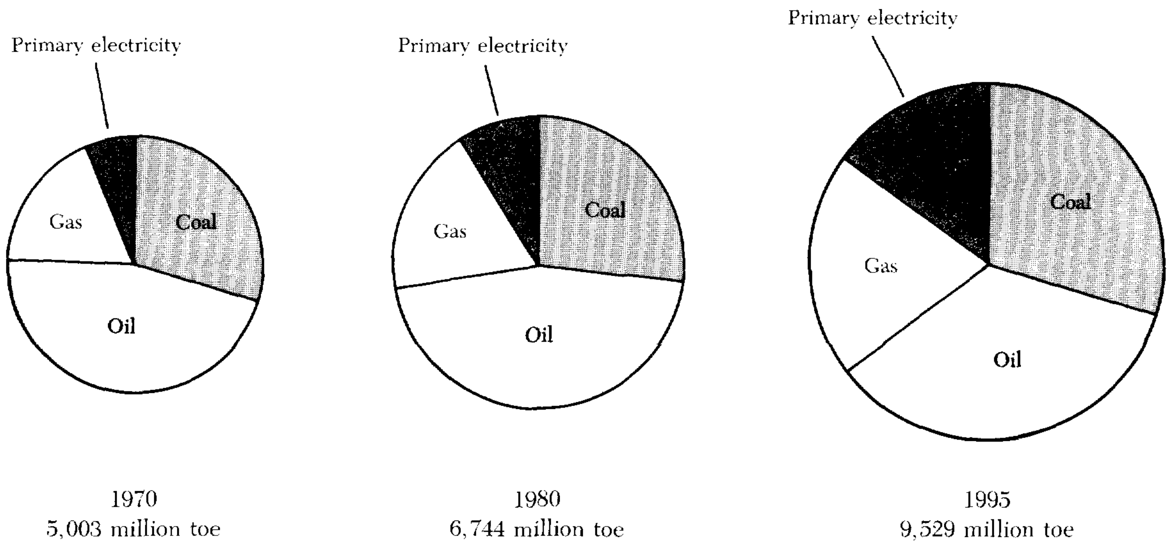
The recent reduction in oil prices has been brought about by a reduction in demand resulting from recession, conservation, and substitution by other fuels combined with a sharp increase in supply from nontraditional producers whose oil resources can be developed profitably at these higher prices. Between 1980 and 1982, world oil consumption dropped by 4 million barrels a day, or about 6.5 percent. Over the same period, the average official OPEC price (in US dollars) declined by 4 percent in real terms.[3] Because of continued depressed demand, spot prices have been well below term prices since the final quarter of 1982, leading to a reduction in the price of marker crude from $34 to $29 per barrel by the first quarter of 1983. Depending mainly upon the timing and strength of economic recovery in the industrial countries, and OPEC's ability to restrict its production, oil prices may drop further in 1983.

While the exact movement of oil prices in the short term remains highly unpredictable, and oil prices may be unusually volatile for many years, the issue relevant to energy strategy and investment planning is the range of prices expected in the late 1980s and 1990s. Analysts do not expect a low price, say in the range of $20–25 per barrel, to be sustainable in the longer run for a number of reasons. First, it would cause a much sharper increase in the demand for oil (than projected in Table 1.1, for example), both because total energy demand would grow more quickly and because a larger share of this demand would be met from oil whose price would be lower relative to prices of other fuels. Second, on the supply side, this additional demand for oil could only be met outside OPEC sources by developing those petroleum resources whose cost at the margin would be higher than $20–25 per barrel. It is now generally agreed that giant oil fields, which could be developed at lower costs than this level, are highly unlikely to be discovered and recent experience has also shown that synthetic fuels, which could substitute for oil, are likely to be much more expensive than was initially envisaged.

In short, while there is considerable uncertainty about the precise rate of the price increase in the next decade, it is extremely unlikely that the price of oil in the mid-1990s will be below

3. The real change in terms of other currencies is different. In terms of the Japanese yen and the French franc, the real price increased in 1982 compared to 1981.

Figure 1.1 *Shares of Fuels in World Commercial Energy Consumption, 1970–95*



its current level in real terms. Developing countries need to plan on this assumption and to accord a high degree of priority to increasing the efficiency of energy use, reducing energy costs by replacing oil imports with cheaper domestic or imported fuels, and improving the management of the energy sector.

Following a slowdown in economic growth to 1.9 percent a year during 1980–82, GDP in developing countries is forecast to grow at an average annual rate of 4.4 percent during 1982–85, increasing to a rate of 5.4 percent during 1985–90 and 5.5 percent during 1990–95.[4] The average rate of 4.8 percent a year for 1980–95 compares with 5.1 percent a year in 1970–80 and 5.9 percent a year in 1960–70. Future energy production and consumption in developing countries will depend to a large extent on whether these projected GDP growth rates are achieved.[5] The projections made in this report also assume the successful implementation of investments, management reforms and policy changes in the energy sector affecting the management of both supply and demand.

Commercial Energy Consumption

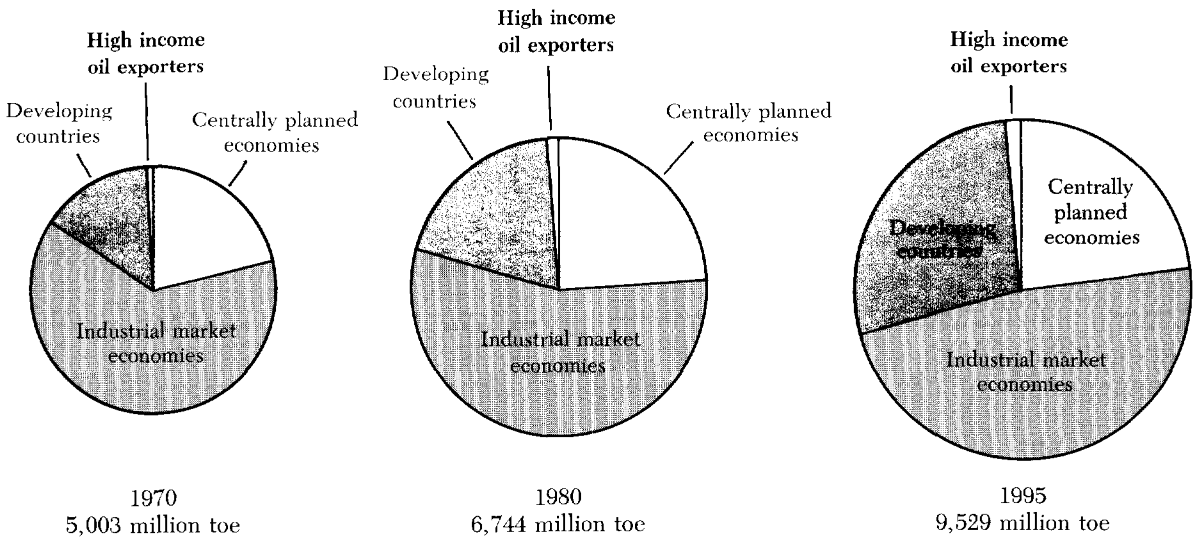
Developing countries account for a small but growing share of the world's commercial energy consumption (see Figure 1.2). During the 1970s, their demand for commercial energy grew at nearly 6 percent a year and their consumption of oil at much the same rate. After the sharp oil price increase of 1979, and the economic recession that followed, commercial energy consumption in these countries stagnated during 1980 and their demand for oil decreased slightly—by about 5 million metric tons of oil equivalent (toe).

Based on the projections of economic growth and energy sector developments, mentioned earlier, in 1980–95, commercial energy consumption in the developing countries is projected to grow at 4.5 percent a year—that is at a lower rate than in the 1970s. The growth in their demand for oil is projected to decrease sharply to about 2.7 percent a year, or less than half the figure for the 1970s (see Table 1.2). Despite this slowing down, energy consumption in the developing countries will continue to grow

4. For analytical purposes, countries are classified into four groups: industrial market economies, centrally planned economies, capital surplus oil exporters, and developing countries. For classification of countries, see page xiv.

5. This is, of course, a two-way relationship: these economic growth projections are themselves unlikely to be achieved without the necessary increase in energy production and supply.

Figure 1.2. *Shares of Country Groups in World Commercial Energy Consumption, 1970–95*



faster than in the rest of the world, partly because their economies are growing faster and partly because increasing industrialization and urbanization will entail a rapid increase in their commercial energy use. As a result, their share in global energy consumption will increase from a fifth in 1980 to just over a fourth by 1995 (see Figure 1.2). This implies that almost half of the projected increase in global energy consumption over the 1980–95 period will take place in the developing countries. In oil, the developing countries' share of incremental global consumption will be greater than 100 percent, because oil consumption in the rest of the world is projected to decline in this period. Within the developing countries, the share of oil in commercial energy consumption is projected to drop from 47 percent in 1980 to 36 percent by 1995. As in the world at large, this will be offset by significant increases in the shares of primary electricity and natural gas.

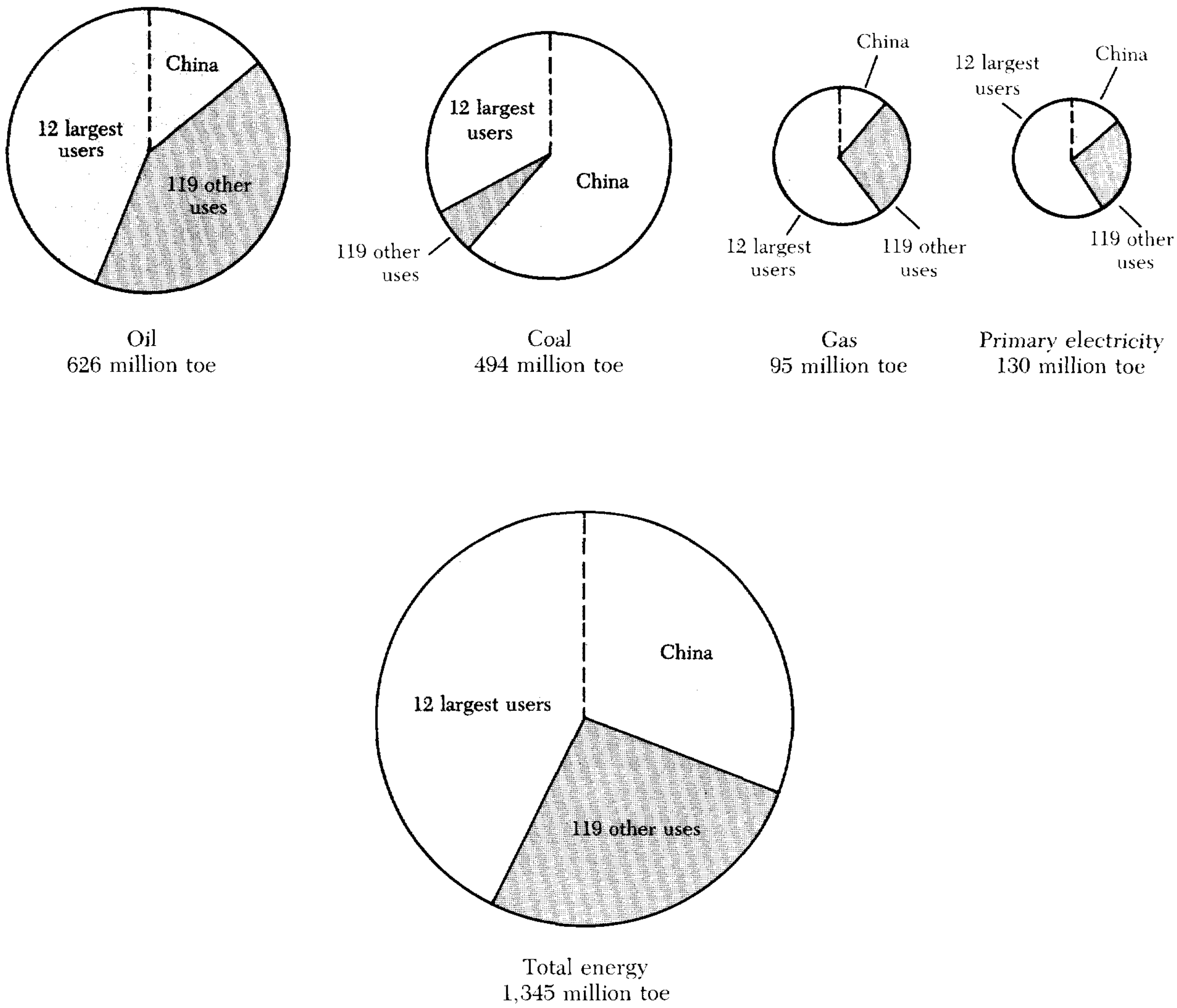
These aggregates are strongly influenced by the energy demand and supply patterns in a few major countries (see Figure 1.3). China alone accounted for about 30 percent of the commercial energy consumption in developing countries in 1980 and about 60 percent of the coal used in these countries. Three other countries (Brazil, India, and Mexico) account for a further 20 percent of the total, and the twelve largest commercial energy users account for over two-thirds of all the energy consumed by 131 developing countries. Moreover, the figures in Table 1.2 do not reflect the importance of oil for most developing countries, because they are heavily influenced by the coal-based energy consumption

Table 1.2. *Commercial Primary Energy Consumption in Developing Countries, 1970–95*

	Million toe			*Growth rate (percentage per year)*	
	1970	*1980*	*1995*	*1970–80*	*1980–95*
Oil	355	626	934	5.8	2.7
Coal	298	494	940	5.2	4.4
Natural gas	47	95	324	7.3	8.5
Primary electricity	56	130	396	8.8	7.7
Total	756	1,345	2,594	5.9	4.5

Sources: UN J Series and World Bank estimates.

Figure 1.3. *Primary Commercial Energy Consumption in Developing Countries, 1980*



patterns of China and India. In developing countries, other than China and India, the share of oil in total commercial energy consumption in 1980 was 61 percent and is projected to fall to 44 percent by 1995.

Commercial Energy Production

Programs to increase domestic supplies have been stepped up in almost all developing countries. Because of long lead times, the full impact of these programs has yet to be felt, but most of them have been successful. New reserves have been identified for a variety of energy sources—most notably oil and gas—and projects to develop already known reserves of petroleum, coal, and hydropower are underway in many countries. Over the last decade, a number of developing countries switched from being oil importers to exporters of oil, including the Congo, Malaysia, and Peru. Several other countries produced oil for the first time; these include Cameroon, Ghana, Guatemala, Ivory Coast, Thailand, and Zaire.

As Table 1.3 shows, the 3.6 percent a year increase in developing countries' commercial primary energy production during the 1970s is expected to be surpassed during the next fifteen years, even though their energy consumption will grow more slowly than in the past. Whereas

Table 1.3. *Commercial Primary Energy Production in Developing Countries, 1970–95*

	Million toe			Growth rates (percentage per year)	
	1970	*1980*	*1995*	*1970–80*	*1980–95*
Oil[a]	774	919	1,375	1.7	2.7
Coal	294	502	886	5.5	3.9
Natural gas	52	116	424	8.4	9.0
Primary electricity[b]	56	130	396	8.8	7.7
Total[c]	1,176	1,667	3,081	3.6	4.2

a. Includes natural gas liquids and oil production from secondary recovery techniques.

b. Includes hydropower, nuclear, and geothermal electricity.

c. Excludes alcohol, oil shale, tar sands, and other nonconventional primary energy sources which may add a small amount (up to 10 million toe, or less than 0.5 percent) to developing country energy production by 1995, but whose prospects are too uncertain to quantify.

Source: Table 3.1.

these countries produced about one-fourth of the world's commercial energy in the 1970s, they are expected to supply about one-third by 1995. As such, they will contribute around half the increase in global production of commercial energy in 1980–95 (see Table 1.4).

As in consumption, the growing importance of developing countries, including the currently oil exporting developing countries, is especially marked in oil, where their share of global production is projected to rise from 30 percent in 1980 to 41 percent in 1995. (See Figure 1.4). Much of this additional oil production will be consumed domestically. However, the developing countries will continue to be net suppliers of oil in international trade; their surplus is projected to increase from 293 million toe in 1980 to about 440 million toe by 1995. Natural gas production in developing countries is also expected to outstrip consumption, reflecting the growth of their gas exports to industrialized nations. In coal, however, the growth of coal imports by 15–20 countries will mean that developing countries as a group will become net importers to the extent of about 54 million toe by 1995.

In interpreting the projections, one should also note that the developing countries' production, like their consumption, is concentrated in a few countries. In oil, for example, 18 oil exporters supplied over 90 percent of total production in 1980. In coal, China and India accounted for 72 percent of total production in the same year. Thus, the energy production of developing countries as a group will depend mainly on the achievements in these major countries. In addition, the forecast production shares also depend on global trends which may affect energy demand in the industrial countries and output from the larger oil exporters.

Table 1.4. *Shares of Developing Countries in World Incremental Production and Consumption of Commercial Primary Energy, 1970–95*
(percent)

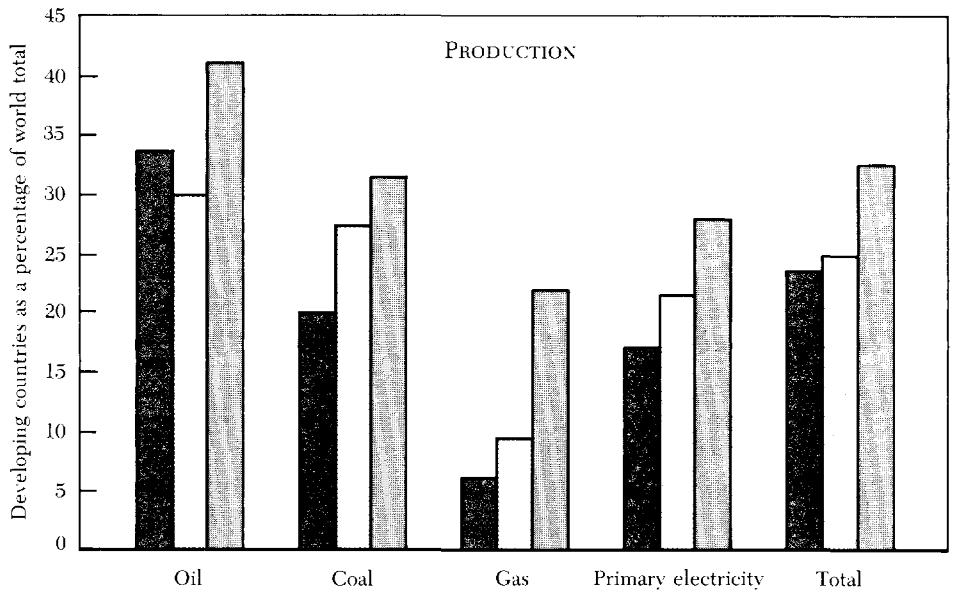
	1970–80	*1980–95*
Production		
Oil	20.5	158.3
Coal	57.6	38.6
Natural gas	18.8	44.7
Primary electricity	26.1	32.8
Total	29.0	50.8
Consumption		
Oil	35.8	106.9
Coal	56.0	44.8
Natural gas	13.6	33.2
Primary electricity	26.1	32.8
Total	33.8	44.8

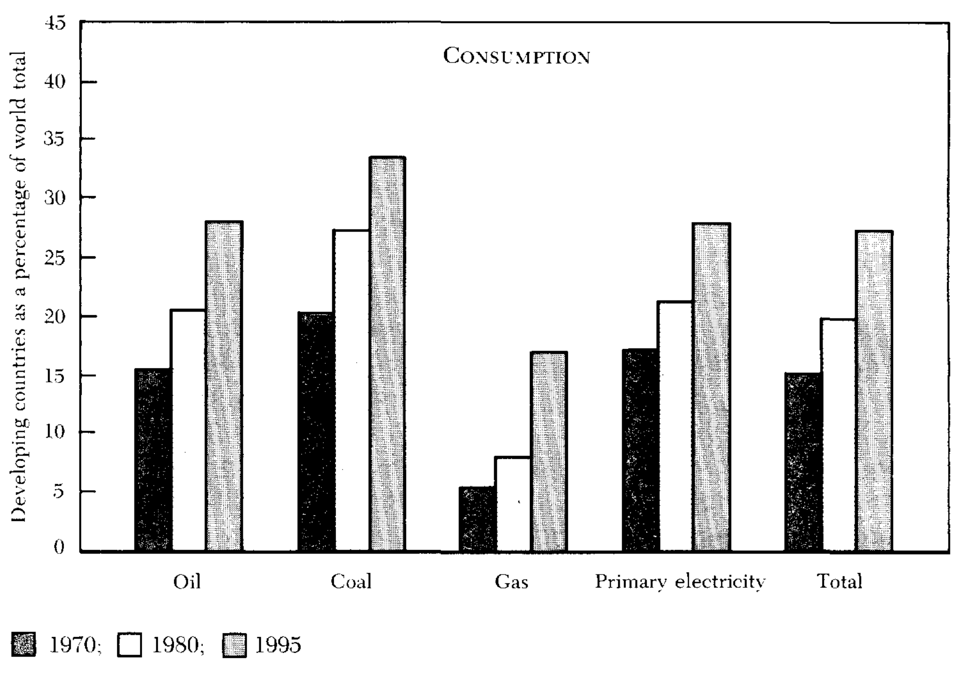
Sources: World Bank estimates.

Oil Importing Developing Countries

Although total commercial energy consumption in the oil importing developing countries is projected to grow at about 5 percent a year, their oil consumption will grow at about half that rate. Oil is projected to account for only about one-fourth of their incremental consumption over

Figure 1.4. *Shares of Developing Countries in World Primary Commercial Energy Production and Consumption, 1970–95*





1980–95, as against its share of about one-half during 1970–80. This is brought about mainly through the accelerated development of their indigenous energy resources. For every type of fuel, the projected growth rate of indigenous production in the oil importing developing countries (OIDCs) exceeds the projections for developing countries as a whole. As a result, their net imports of oil are projected to drop from 44 percent of their commercial energy consumption in 1980

Table 1.5. *Commercial Primary Energy Production and Consumption in Oil Importing Developing Countries, 1970–95*

	Million toe			Growth rates (percentage per year)	
	1970	1980	1995	1970–80	1980–95
Production					
Oil	63	65	145	0.3	5.5
Coal	118	192	384	5.0	4.7
Natural gas	14	27	115	6.8	10.1
Primary electricity	41	98	306	9.1	7.9
Total	236	382	950	4.9	6.3
Consumption					
Oil	223	360	531	4.9	2.6
Coal	121	186	442	4.4	5.9
Natural gas	12	26	120	8.0	10.7
Primary electricity	41	98	306	9.1	7.9
Total	397	670	1,399	5.4	5.0
Oil Imports	160	295	386	6.3	1.8

Sources: United Nations J Series and World Bank estimates.

to about 28 percent in 1995. Nevertheless, oil will continue to be a major source of energy for them, supplying about two-fifths of their commercial energy consumption in 1995 (see Table 1.5). Thus, despite considerable efforts to substitute for oil, the net oil imports of the OIDCs are expected to continue growing, from 295 million toe in 1980 to an estimated 386 million toe in 1995.

Renewable Energy

Nearly all developing countries face a major challenge in developing renewable sources of energy. Not only must they confront the crisis in the supply of the traditional biomass fuels, the main source of energy for rural households, but they must also exploit the possibilities—many of which have only recently become profitable—for using biomass, solar, and other renewable resources to provide energy in rural areas and to replace petroleum.

As a group, developing countries consume as much biomass energy as they do commercial fuels. In ten of the thirteen countries for which the Bank has completed energy assessments, biomass fuels supply more than half of the total primary energy consumed. In three of these countries, the proportion of energy derived from biomass is 90 percent or greater and the average for the group exceeds 65 percent. Current consumption levels have already caused severe problems in many countries. In the group of ten countries, mentioned earlier, it is estimated that the consumption of woodfuels is greatly outstripping sustainable production, sometimes by a factor of three or four. At present rates of exploitation, accessible forest resources in many countries will be practically obliterated within 20 to 30 years. The situation is a grave one, not only because biomass fuels are an important energy source, but because they are used by the majority of the population who have no real alternative other than a deterioration in living standards. Moreover, the problem of deforestation is not just an energy problem; it has important agricultural and environmental causes and consequences. The clearing of land for agricultural purposes has been an important cause of deforestation, while the loss of forest cover and organic residues leads to soil depletion and declining agricultural productivity.[6] Within the energy sector, siltation of reservoirs and river systems is detrimental to the development of hydropower potential. It is essential that developing countries improve the efficiency with which

6. Such as crop residues and dung which are increasingly used as fuel instead of serving their other traditional role as fertilizers.

wood and combustible residues are both produced and consumed to alleviate the mounting pressure on energy, agriculture, and the environment. Stepped up tree planting programs, improved management of existing forest resources, the introduction of more efficient wood stoves and charcoal kilns, and the development of alternative cooking fuels are all important parts of the attack on the fuelwood problem.

Heterogeneity of Developing Countries

Different countries in the developing world face very different energy problems and prospects. The most obvious distinction is between oil exporters and oil importers which have been affected in very different ways since 1973. For the developing countries that export oil, the principal result of the oil price increases has been a major increase in inflows of foreign exchange, opening up additional options for development investment. These countries face two sets of energy issues. At the macroeconomic level, they need to ensure that their economic policies do not discourage the production of exportable goods other than oil, and to maintain an appropriate pace of petroleum exploration and production. A second set of issues, which oil exporters share with oil importers, is to adjust their energy consumption and production patterns to take account of higher energy costs. In this area, the oil exporters have generally made slower progress than the OIDCs and, in some of them (for example, Ecuador, Egypt, Indonesia, Peru, or Tunisia), the rapid growth of domestic oil consumption, if left unchecked, could virtually eliminate their exportable surplus in the next decade.

Apart from the oil importer/exporter distinction, a number of other classification criteria are relevant. Among the oil importers, the share of export earnings absorbed by oil imports is a good indication of the direct impact of higher oil prices on the balance of payments and of the resulting reduction in real national income caused by the implied adverse shift in terms of trade. This ratio varies a great deal depending on the importance of trade in the economies, the level of industrial and transport activity, and the availability of alternative energy sources. For a sample of 39 OIDCs in 1980, payments for net oil imports took over one-half of merchandise export earnings in seven countries, between one-fourth and one-half in 17 countries, and less than one-fourth in the remaining 15 countries. Another dimension of dependence on imported oil is shown by the share of oil imports in a country's total commercial energy consumption. About half of the OIDCs, including many of the poorest ones, rely on imported oil for over three-fourth of their commercial energy requirements; these countries have been especially badly affected by higher oil prices.

The distinction between low and middle income countries is also relevant: first, because the poorer countries generally have had the least scope for reallocating resources from other parts of the economy to pay for energy imports and, second, because they have also had the greatest difficulty in borrowing commercially to pay higher oil import bills in the short run. An important point made in Chapter 5 of this report is that the low income countries' limited access to commercial borrowing will make it particularly difficult for them to invest in developing their own substitutes for imported oil.

Finally, a country's potential to reduce its energy costs by developing indigenous energy sources depends upon its own energy resource endowment. As these endowments are always imperfectly known, it is difficult to use them as a precise basis for classification. Nevertheless, based on the developing countries' known, economically developable commercial energy resources in relation to their energy needs, they can be classified into the three broad groups shown in Table 1.6. Countries in the first group have limited opportunities to lower their energy costs because their own energy resources are small or extremely costly to develop (for example, Burundi, Haiti, Nepal, or Rwanda). It is important to note that physical resource availability alone is not a sufficient criterion. Nepal, for example, has an enormous hydropower potential in relation to its needs, but precisely because these needs are so small, the larger and cheaper hydrosites cannot be developed economically unless agreement can be reached on exports of electricity to neighboring India.

At the other end of the spectrum are countries endowed with substantial reserves of primary energy, such as cheap hydropower, or abundant coal, oil, gas, or lignite. Some countries in this group, such as Bolivia, Cameroon, and Colombia have abundant resources of oil, gas, or coal and are or could become exporters of some of these fuels. Oil-importing countries in the group include Colombia and India. These countries are generally in the process of replacing imported oil with cheaper domestic energy. India, for example, is raising its own oil production, accelerating the development of large-scale hydroelectric projects, replacing oil-fired by large coal-fired generating plants, and economizing on transport costs through railway electrification and on irrigation costs through rural electrification.

Many developing countries with moderate amounts of one or several energy resources find themselves between the two extremes. In some (for example, the Philippines and Tanzania), resources have only recently been found and are still being assessed with production having just started. Other countries in this group (for example, Kenya and Costa Rica) are less well endowed with domestic energy resources, but are in a position to reduce the cost of imported energy by substituting cheaper fuels such as coal.

Alternative Scenarios

As indicated earlier, the report's projections of energy demand and supply in the developing countries are based on quite favorable assumptions about economic prospects and energy sector developments. Varying any of these assumptions would result in different energy supply and demand projections, but the policies and strategies recommended in the report would remain largely unaltered. For example, lower economic growth, than assumed here, could result in lower energy consumption than projected, but this would be a less desirable alternative. Slower economic growth would also reduce the level of energy investments required, but their relationship with GDP would likely be unchanged, so that adequate financing would still be difficult to find.

Another source of uncertainty is the precise evolution of international energy prices in the short term and their impact on domestic pricing and investment policies. As indicated earlier, the underlying trend of oil prices will remain a high and moderately rising one even though there may be quite sharp short-term fluctuations in response to market conditions. The above projections assume that developing country governments will base their retail pricing and investment policies on these underlying trends and will not slow down their efforts to manage energy demand or their programs to increase the production and use of alternative energy sources. Slower progress in either of these areas would raise oil consumption above that projected here. Less effective energy demand management would both raise total energy consumption and increase the share of oil in this consumption because, for technical and institutional reasons, potential substitutes for oil are unlikely to be made available more quickly than projected. If indigenous energy resources are developed more slowly than anticipated here, the demand for oil would again increase to compensate for their reduced availability, even if the total demand for commercial energy remained unchanged. In both cases, this higher demand for oil is unlikely to be financially sustainable and the more probable outcome would be a curtailment of economic growth for these countries.

In Chapter 5, the investments that will be needed to meet the projected energy demand of developing countries are discussed. These amount to about 4 percent of developing countries' GDP and will pose a formidable financing problem. However, all these investments are economic, and the bulk of them would remain so even if the long-term price of oil were to fall to, say, $25 a barrel (1983 dollars). Virtually all of the oil and gas development projects proposed in both the oil exporting and oil importing developing countries would continue to yield satisfactory economic returns at this price. For example, the costs of incremental oil production in the six major OIDC oil producers (which account for three-fourths of OIDC oil production) range from $10 to $20 a barrel. The costs of gas production in the developing countries are so far below the price of oil substitutes that there is little doubt about the economic benefit of exploiting gas, provided there is a market for its use. The costs of coal development in the larger coal producers (China and India) are similarly well below the limits imposed by oil substitution even at a $25

Table 1.6. *Commercial Energy Typology of Developing Economies*

Energy resources or options (relative to country size)	*Oil exporters*		*Oil importers* — *Net oil imports as a percentage of primary commercial energy consumption in 1980*			
	Large	*Small or medium*	*0–25*	*26–50*	*51–75*	*76–100*
LIMITED			Middle income Lesotho Namibia		Low income Burundi Kampuchea Lao PDR **Nepal** Rwanda	Low income Bhutan **Ethiopia** Guinea Bissau Haiti Niger Somalia **Sri Lanka** Togo **Upper Volta** Middle income Barbados Cuba **Dominican Republic** Hong Kong Israel **Jamaica** **Jordan** Lebanon Liberia Mauritania Singapore **Uruguay** **Yemen AR** Yemen, PDR
MODERATE		Middle income *Syria, AR*	Low income Zaire Middle income Botswana + Korea, PDR + Vietnam Zambia + Zimbabwe	Low income Ghana * **Pakistan** Middle income * + ***Brazil*** * Chile Guatemala Ivory Coast Mongolia	Low income * **Bangladesh** Central Afr. Rep. Chad Equatorial Guinea Malawi Mozambique **Uganda** Middle income Costa Rica El Salvador Honduras + **Korea, Rep. of** **Paraguay** **Portugal** + **Turkey**	Low income **Benin** Guinea Madagascar Mali Sierra Leone **Sudan** **Tanzania** Middle income + **Greece** **Kenya** **Morocco** **Nicaragua** **Panama** Papua New Guinea **Philippines** **Senegal** **Thailand**
SUBSTANTIAL	Low income * + *China* Middle income * *Indonesia* * *Iran* * *Iraq* * + *Mexico* * *Nigeria* * *Venezuela*	Middle income * *Algeria* *Angola* Congo, PR *Ecuador* * *Egypt* *Gabon* * *Malaysia* * *Peru* * *Trinidad & Tobago* *Tunisia*	Low income Burma * + ***India*** Middle income * *Argentina* Cameroon * + *Colombia*	Low income * Afghanistan Middle income * + **Yugoslavia**	Middle income * Bolivia	

a barrel oil price. However, some coal development projects, particularly of low-grade lignite, will be affected, especially if they involve large infrastructure investments. Some coal import projects will also be affected, particularly those where quantities are small and heavy infrastructural investments are required; but it is important to note that the investments for these projects are not included in the estimates made in this report. In electric power, the vast majority of hydropower projects would continue to be economically viable at a $25 a barrel oil price, although a few of the planned small projects which are marginally viable even now will become uneconomic. Finally, the extraordinarily high rates of return and quick payback periods of almost all projects to improve energy efficiency ensure their continued viability at much lower energy prices.

Thus, although a definitive judgment on the economics of the investments proposed in this report can only be made after a detailed cost-benefit analysis on a project-by-project basis, there is adequate evidence to indicate that the bulk of them would remain high-priority investment opportunities even if long-term international oil prices fell by as much as 20 percent.

The basic explanation underlying this conclusion is that the vast majority of developing countries have still not completed their adjustment process to the dramatic energy price changes of the last decade. At current energy prices, the bulk of the proposed investments have relatively high economic rates of return and, as such, their economics remain strong even if current price relationships are altered significantly. Thus, while the actual projections of energy supply and demand should be interpreted as illustrative and subject to a margin of error, the essential conclusions and recommendations of this report remain robust under a broad range of plausible assumptions.

Note to Table 1.6: Not shown are economies with less than one million population and without production (or prospects of future production) of oil, gas, or coal. The economies included in this table are classified according to their energy resource potential (oil, gas, coal, and primary electricity) that could be economically developable during the next decade. Oil exporters are countries whose official earnings from net oil exports exceed 10 percent of their total export earnings in 1980–81. *Large oil exporters* refers to those countries that produced more than 70 million toe during 1980.

– Produced two or more million toe of coal in 1980.

* Produced one or more million toe of gas in 1980.

Economies shown in *italics* produced more than 5 million toe of oil in 1980.

Economies shown in **bold print** had net energy imports amounting to 30 percent or more of their merchandise exports in 1980. (Information is not available for all countries).

Source: World Bank.

2. Energy Demand Management

Demand management is necessary for two reasons: to reduce the energy used per unit of output in the economy and to induce a shift from high-cost sources of energy towards cheaper ones, either domestic or imported. Recent experience shows that both effects can be achieved by the use of a range of demand management methods.

Most of the experience with energy conservation has been gained in the industrialized countries, where a variety of programs have successfully reduced the energy used for a given level of economic activity. There are many obvious differences between industrialized and developing countries in the level of energy consumption per capita and in the sectoral pattern of energy consumption. However, there is a growing body of evidence—including the energy conservation projects and energy sector assessments carried out by the Bank—which indicates that in developing countries, too, substantial energy and cost savings through better demand management are both feasible and cost effective. Many developing countries have embarked on programs to influence demand for various sources of energy, but few have as yet formulated comprehensive strategies for managing energy demand.

In most low income countries, national levels of commercial energy intensity (measured as tons of oil equivalent used per $1,000 of GDP) are below those in the industrialized countries, but middle income developing countries are generally at least as energy intensive. Some developing countries, notably India, Republic of Korea, and Yugoslavia are close to, while others, such as China, are even well above the levels of the most energy-intensive industrialized countries (see Box 2.1). In energy-intensive industries, many industrial plants in developing countries have been found to consume 10 to 30 percent more energy per unit of output as best international practice and some consume over twice as much.

Many oil-using plants can be converted to use other fuels (coal and gas, for example) costing 50 to 80 percent of their petroleum fuel equivalent; many transport enterprises could reduce consumption per ton-kilometer by 10 percent or more through low-cost improvements and by much more if the designs of vehicles and engines are modified; electric power transmission and distribution losses could typically be reduced by amounts equivalent to at least 5 percent of the total electricity generated; and improved woodstoves for residential cooking require only half as much wood as traditional stoves.

Developing country policymakers are becoming increasingly aware of this potential. A few countries, notably Brazil, China, and the Republic of Korea, have reduced their national commercial energy intensity in the last few years, and made a shift towards cheaper substitutes for petroleum fuels. The substitution efforts already underway in other developing countries include the replacement of oil by gas in Bangladesh, Bolivia, and Pakistan; by coal in Zambia; and by bagasse in Mauritius. In the vast majority of developing countries, however, this process has barely begun and progress will require the resolution of a variety of institutional, policy, and informational difficulties and the development of a well defined national energy demand management program.

Box 2.1. *What Determines Energy Consumption? Some Cross-Country Comparisons*

Although it is obvious that energy is essential for economic development, it is less obvious why its use differs so much among economies at similar levels of development. For example, India's or China's per capita consumption of total commercial energy could be considered "abnormally" high in comparison to that of other low income developing countries, and per capita energy use in the U.S. has exceeded that in Sweden by 50 percent or more in recent years.

To improve knowledge of the determinants of energy consumption, a recent Bank-sponsored study has analyzed cross-country variations in the consumption of total commercial energy, commercial energy plus fuelwood, petroleum, and electricity for two periods, 1969–71 and 1976–78. The models of energy demand used in this study relate intercountry differences in per capita use of energy to differences in (a) per capita GDP and population, (b) petroleum product prices, (c) energy-related aspects of economic structures not fully reflected in per capita income differences, and (d) winter temperature (to reflect requirements for space heating).

The study finds that:

- For all four categories of energy, per capita GDP plays, by far, the largest role in explaining intercountry differences in per capita use.
- Petroleum product prices are significant for explaining intercountry differences in petroleum consumption.
- The production of energy-intensive materials is an important determinant of energy use for each of the four energy categories considered in the study.
- Winter temperature has a significant influence on intercountry differences in consumption of commercial energy plus fuelwood. However, because of the correlation of temperature with structural factors and with GDP, it has less influence on commercial energy consumption than might have been expected.

Taking account of all four explanatory variables, the responsiveness of energy use to changes in per capita income was quite stable over the two time periods. The income elasticity of demand for energy was about 1.08 for commercial energy, 1.10 for petroleum consumption, 0.90 for commercial energy plus fuelwood, and 1.17 for electricity. The price elasticity of demand for petroleum in non-OPEC countries was -0.55.

Measures for Managing Energy Demand

The specifics of such a national energy demand management program must obviously vary from country to country, but it is possible to identify four broad categories of measures that can be used to achieve the twin goals of raising energy efficiency and replacing costly sources with cheaper ones.

- Energy pricing policies.
- Taxation and other fiscal incentives.
- Direct capital allocation.
- Technical assistance, training programs, regulations, and promotional and educational programs.

Pricing

The most important of these measures is an energy pricing strategy which provides energy users with an incentive to eliminate energy waste and to choose fuels on the basis of their costs to the economy. In recent years, many developing countries have recognized the central importance of pricing in strategies to manage the energy sector, and have begun to raise prices to reflect increased costs, especially those of petroleum fuels. However, in some areas and countries there is still a tendency to keep energy prices considerably below opportunity costs.

In the oil importing developing countries, increases in the costs of oil have generally been passed on fully and promptly to final users and the weighted average of retail prices of petroleum products is higher than import parity in nearly all of them. In many countries, the increase in retail prices has been quite substantial in recent years: the real domestic price increase of petroleum products in terms of local currency between 1975 and 1981 was about 40 percent in Korea; about 60 percent in Brazil, Pakistan, the Philippines and Turkey; and over 200 percent in Colombia and Yugoslavia.

The situation is more mixed in the electricity sector of oil importing countries. Of 33 countries surveyed recently, 18 have increased their tariffs in real terms since 1974, and some (for example, Pakistan, Sri Lanka, and Thailand) by as much as 50 to 100 percent. Nevertheless, only seven of these countries have electricity tariffs that are equal to or exceed the long-run marginal cost of supply. Basing electricity tariffs on the long-run marginal cost ensures that both the level and structure of tariffs reflect the cost of expanding the power system. An increasing number of countries (among them Bangladesh, Indonesia, Kenya, Nigeria, and Sri Lanka) have recently committed themselves to considering the economic cost of supply in setting tariffs.

In the oil exporting developing countries, domestic retail prices of energy are generally still well below international levels and in a number of cases have fallen in real terms since the mid-1970s. Relative price distortions are also more pronounced in these countries; for example, in 1979, prices of diesel fuel were only about 40 percent of those for gasoline, as compared with about 60 percent in the oil importing countries, and 90 percent in international trade. Some of the oil exporting developing countries have recently improved their petroleum pricing policies substantially, but further progress is needed. This is particularly important in those countries (such as Egypt, Indonesia, and Nigeria) where the rising domestic demand for petroleum products is reducing the available exportable surplus, with potentially serious macroeconomic consequences.

Pricing is an essential instrument of energy demand management not only because of its direct effect on the level of energy consumption, but also because it indirectly affects consumption by influencing the choice of energy-using technology. If energy prices are set below the economic cost of supply, the wrong priorities may be set for investments that will consume energy and technologies may be chosen whose use is not in the nation's economic interest. Some countries, such as Egypt, might not have developed such energy-intensive industries as aluminum smelting had their power prices reflected long-run economic costs. Others, such as Brazil, might have given greater emphasis to rail transport if diesel fuel had not been subsidized. Moreover, at artificially low prices, energy users will not have enough financial incentive to improve the efficiency of energy use. Investments in improved boilers, systems to recover waste heat, heat exchangers or process changes, are not likely to be profitable if the equipment has to be purchased at commercial prices but the fuel saved is subsidized.

The relative prices of different energy sources strongly influence interfuel substitution. In an economy where fuel oil prices are subsidized, the commercial development of indigenous coal resources may require a subsidy on coal as well. Similarly, a subsidy on kerosene may reduce the flexibility to set diesel oil prices: a wide differential would cause diesel oil users to switch to cheaper kerosene.

Changes in relative prices can have substantial effects on consumers' choice of fuels. Prices of diesel oil in the oil importing developing countries for which data are available rose from 38 percent of gasoline prices in 1975 to 61 percent in 1979 as diesel subsidies were reduced. The pattern of consumption changed in response: for example, Pakistan's diesel oil consumption decreased from about 550 percent to about 300 percent of its gasoline consumption in five years. In contrast, Brazil's decrease in the price of diesel oil relative to that of gasoline contributed to diesel oil use increasing from about 90 percent to about 150 percent of gasoline use during the same period.

The discussion, thus far, has focused primarily on the role of pricing in energy demand management, but the pricing of energy has a much wider impact. As shown in Chapter 3, apropriate producer pricing policies will be a key element in increasing the participation of the private sector in the development of indigenous oil, gas, and coal. Where public agencies are responsible for energy production and supply, appropriate pricing will be necessary to generate sufficient resources for investment and to ensure the financial viability of these agencies. As discussed in Chapter 5, the resource mobilization aspect of energy pricing, particularly for electricity, is an area which requires urgent attention in many developing countries.

However, it is important to recognize that decisions on energy pricing can be politically and socially difficult and require a phased approach based on careful analysis. For example, it is not always easy to establish precisely the economic costs of specific fuels, which may vary with estimates of reserves or the potential of the market. Sometimes, it is even difficult to establish the landed cost of imported fuels because of ambiguities concerning international freight costs or sources of supply. The implications of different price structures for the level of demand (for example, peak consumption of electricity, relative shares of gasoline, or diesel in transport) and, in turn, the implications of the level of demand for the design of power systems and refinery configurations, also need to be taken into account. Adequate analysis of these issues calls for a detailed study. In the Bank's experience, a thorough study of energy pricing in a country may need 10 to 25 staff months of analysis, assuming that the relevant information, for example on production costs and expansion plans, is readily available.

Such a study would also address two concerns which frequently prevent governments from lowering subsidies on consumer prices: the need to hold down inflation and to provide lower income families with an affordable supply of energy. Although the exact circumstances vary among countries, there is now a growing body of evidence that these concerns are exaggerated. First, in most industries, energy accounts for a relatively small proportion of the total costs of production and the exceptions—such as cement, fertilizer, or aluminum—are not a large part of industrial production in most developing countries. Adjusting energy prices to their economic costs, therefore, has a limited effect on total industrial production costs. For example, a recent study for Egypt demonstrated that the inflationary effects of large and continuing energy price increases is likely to be small: even if demand is completely unresponsive to changes in price, a 30 percent annual increase, on the average, in petroleum product prices between 1980 and 1990 would translate into a less than 4 percent a year average increase in the consumer price index over the same period. Second, most energy consumption surveys have shown that, particularly in the poorer countries, the use of commercial energy is largely concentrated among the middle and upper income groups, while the poor rely primarily on wood and other noncommercial fuels. The energy needs of the poor could well be better served if some of the resources spent on subsidizing commercial fuels were diverted to expanding fuelwood production or for strengthening programs to promote improved woodstoves.

Other Measures

While an appropriate energy pricing policy is an essential feature of an energy demand management program, other types of measures may also be necessary to improve energy efficiency. There are a variety of reasons for this. First, energy users, either individuals or firms, may simply be unaware of the potential for using energy more efficiently or of the technical options available for doing so. This is particularly true in developing countries where access to recently developed energy-efficient equipment and techniques is limited and where an indigenous energy conservation industry has yet to emerge. Second, as with any "new" technology, there is still considerable skepticism that dramatic improvements in efficiency can really be brought about; a skepticism which energy users in industrialized countries are only now starting to overcome after the success of recent years. Third, institutional or policy factors may reduce interest in saving energy. For example, many large enterprises have their input and output prices regulated. This is typical of many of the energy-intensive industries (steel, cement, and fertilizers) in a wide variety of countries (Brazil, China, Egypt, and Turkey). The managers of these enterprises may have little incentive to invest in reducing their energy costs if they are able to pass on these costs to their consumers, or if, as is often the case, they are not sufficiently profit-oriented or are protected from competition. Finally, capital shortages and imperfections in the financial markets, or in the allocation of public or private capital, may make it difficult to obtain finance for economically attractive projects that improve the efficiency of energy use but do not expand capacity.

Promotional and educational programs may be used to raise awareness and reduce attitudinal barriers to improved energy efficiency. Many countries have also introduced more intensive training and technical assistance to provide industrial and commercial enterprises, farmers, and householders with technical services to analyze and improve their management of energy consumption. Regulations may require more energy-efficient standards for industrial and transport equipment, buildings, and appliances. And finally, adequate finance should be made available for economically viable energy conservation projects.

The potential of these options varies across the consuming sectors and by the type and size of the user at whom the program is directed. It is important to identify the sectors where the greatest impact can be achieved with a reasonable effort, and to design a strategy that uses all available policy tools to meet the targets in these sectors. The following sections review the potential for increasing the efficiency of energy use in the main energy using sectors and identify the measures that could form part of an appropriate demand management program in each.

Industry

Industrial energy consumers can be classified into two groups. The first group comprises the energy-intensive industries in which energy costs represent a large share of total production costs (between 15 and 50 percent and occasionally even higher). These include iron and steel, cement, pulp and paper, chemicals, fertilizer, aluminum and petroleum refining; these account for about half of the total commercial energy consumed in industry in the developing countries. For these industries, changes in the cost of energy have a crucial impact on the costs of production and profitability, but their response to higher energy prices is often limited by the regulated conditions under which they operate and by their lack of human and financial resources to apply the technical options that are available for reducing these energy costs.

The recent experience of the industrialized countries has shown that energy costs per unit of output in these industries could be significantly reduced through a variety of measures, ranging from better housekeeping, energy management, and improved monitoring and control systems to more capital-intensive investment in retrofitting existing equipment and using more energy-efficient processes. In most of the industrialized countries, for example, energy consumption per ton of steel and cement decreased by 5 to 15 percent between 1975 and 1979. The share of petroleum fuels in industrial energy consumption declined between 1973 and 1980 from 60 to 57 percent in Japan, from 52 to 43 percent in Germany, and from 54 to 41 percent in the United Kingdom, with the increasing substitution of natural gas, coal, lignite, and electric power.

A first step in realizing such savings is to carry out "energy audits" for each of the major industrial energy users to analyze their existing pattern of energy use and to identify the areas for improving efficiency. Follow-up training and technical assistance are generally necessary for implementation. Special financial support may also be required. Possibilities for reducing energy intensity and substituting cheaper energy forms for petroleum in the energy-intensive industries have been identified in virtually every country covered under the UNDP/World Bank Energy Assessment Program, as well as through other Bank sector and project work.

Even with small investments, mainly of a housekeeping nature, substantial energy savings are possible and paybacks are extremely fast (see Table 2.1). To realize the bulk of the potential savings would require larger investments and the replacement of inefficient equipment, but the payback period of such undertakings is still generally less than five years, and they earn economic returns of 17 to 50 percent a year. This type of investment also helps to remove plant bottlenecks and permits increased output, as well as reducing energy costs.

The second group of industrial users comprises a multitude of medium-sized and small energy consumers. The potential energy savings for this group as a whole are also substantial, but they are unlikely to be achieved as quickly, and direct public intervention in large numbers of enterprises is difficult. The appropriate strategy towards this group is to facilitate the flow of information on techniques for improving energy efficiency and to ensure that energy prices provide appropriate signals. In this context, stimulating the supply of energy conservation equipment and more efficient energy consuming and conversion appliances, for example, by ration-

Table 2.1. *Potential Energy Savings in Selected Industries in Developing Countries*

Industry	*Total developing countries' commercial energy consumption (million toe per year)*	*Potential savings (percent)*	
		Category A	*Category B*
Iron and steel	109	3	15–20
Petroleum refining	54	7	15–25
Cement	52	11	18–28
Chemicals (ammonia)	19	2	20–25
Pulp and paper	15	11	12–15
Aluminum	13	2	10–15

Note: Category A refers to small investments consisting mostly of combustion efficiency improvements, insulation, steam system efficiency improvements, and other housekeeping measures; paybacks within 10 to 20 months.

Category B refers to large investments in retrofitting existing plants and additions to facilities, including waste heat recovery, combined heat and power generation, increased use of waste fuels, simple process changes and controls, and replacement of inefficient equipment; payback in 2 to 5 years. Savings in categories A and B are not necessarily additive in specific plants.

Source: World Bank estimates.

alizing the relevant import policies and investment incentives or by encouraging the production of equipment under license or in joint ventures, is likely to be particularly important. Supporting the development of a local energy audit and conservation industry and an imaginative involvement of development finance institutions can also serve to accelerate energy savings in industry.

Industrial energy management programs are receiving much attention in Brazil, China, and the Republic of Korea. In China, major emphasis is put on replacing oil with coal, rationalizing regulations or quotas, shifting from heavy to light industry, and establishing energy conservation technical centers. In Brazil, the government has established protocols with major industries, particularly for petroleum substitution; it has also created a special fund for investments in conservation and substitution. The Republic of Korea has undertaken audits of major industries. Most developing countries, however, are giving far too little emphasis to improving industrial energy efficiency. The World Bank and a number of other agencies have gained considerable experience in this area in the last few years having financed a number of audit programs and investments to improve energy efficiency in industry. The World Bank is considering a growing number of such operations, particularly in refineries, cement, steel, fertilizers, and paper (see Box 2.2).

There are also a number of opportunities to improve the efficiency of the industrial use of fuelwood and other biomass fuels. For example, in many countries the introduction of more modern kilns can raise the amount of charcoal produced from wood by about 40 percent. Industrial fuelwood consumption could be much reduced through programs directed at rural industry (tobacco curing, tea drying, or brick making) which uses almost as much fuelwood as the household sector in many developing countries. Such a program can be relatively easy to implement (as compared with programs to improve the efficiency of household wood use) because there are relatively few users and they are more easily reached.

Transport

The modern transport sector relies almost exclusively on petroleum fuels and, depending on the industrial structure of the country, it consumes between 20 and 40 percent of the petroleum consumption in developing countries. As opportunities for fuel substitution in transport are very limited, it is especially important to increase the efficiency of energy use in this sector. The mix of transport modes (road, rail, air, marine, and pipeline) varies widely among countries and has a dramatic impact on the overall intensity of energy used in the transport sector. Automobiles typically consume two to three times more energy per passenger-kilometer than buses or railways at reasonable levels of capacity utilization, while truck transport consumes three to ten times more energy per ton-kilometer than rail freight, pipelines, or maritime transport. Such figures tell little about the comparative total cost and convenience of different modes, but they

Box 2.2. *The World Bank's Role in Improving Energy Efficiency*

During the last two to three years, the Bank has addressed the task of improving energy efficiency in the developing countries on several fronts. The joint UNDP/World Bank Energy Assessment Program (see Box 4.3) has increased awareness of the scope for energy savings, particularly in industry and transport and the electric power subsector. Follow-up is planned as part of the Energy Sector Management Program. The assessments have identified substantial scope for reducing energy consumption per unit of output (in Sri Lanka and Turkey, for example) as well as opportunities for substantial reductions in energy costs by replacing petroleum with cheaper fuels, particularly in industry and power. In a number of cases, the Bank is following up through further technical assistance and projects (gas conversions for industrial consumers in Bangladesh; bagasse development for power in Mauritius).

The Bank's lending to improve energy efficiency and its preparation of energy conservation projects are increasing markedly: a number of structural adjustment loans have addressed the need for energy conservation (for instance, in the Republic of Korea, Turkey, and Guyana), with emphasis on improved pricing policies and energy audits. Industrial energy audits in the Republic of Korea, for example, have identified a number of large industrial plants where fuel savings of 20 percent and more are possible with relatively modest investments having payback periods of less than one year. A number of loans have been made and are in preparation for modifying existing processes and for converting to cheaper fuels in energy-intensive plants (these include refineries in Argentina and India, steel in Egypt, cement in Portugal, and fertilizers in Turkey). Technical assistance has been provided for energy audits and institutional strengthening for energy conservation in various countries (Argentina, Barbados, Panama, Portugal, Turkey, and Yugoslavia).

Many of the Bank's lending operations in energy and industry have addressed energy pricing policies, helping countries towards more rational and efficiency-oriented pricing for the various forms of energy (for example, power tariffs in Tunisia, gas prices in Thailand, petroleum prices in Morocco and Pakistan, and coal prices in Indonesia). Energy pricing is frequently discussed as part of the dialogue on structural adjustment lending.

A number of operations will improve power distribution systems (for example, in Burundi and Jamaica) and thereby reduce heavy distribution losses. Recently, the Bank has developed and begun to implement, with UNDP assistance, a pilot program for Power System Loss Reduction (see Box 2.3).

The Bank is supporting studies on how to improve energy efficiency in transport (for example in Brazil, India, and the Republic of Korea), and a number of urban traffic management projects have been designed to alleviate congestion and thereby reduce automotive fuel consumption. A recent railway modernization project in India includes a component to improve diesel locomotive fuel efficiency.

Efforts to make the consumption of fuelwood and other biomass fuels more efficient include the promotion of better woodstoves in agriculture and rural development projects, for example in Burundi, India, Nepal, and the Philippines. A number of energy assessments have identified scope for substantial savings of fuelwood in industry (for example in tobacco drying in Malawi).

indicate that strategies designed to influence the transport mix should take explicit account of energy costs and the availability of alternative transport fuels. Typically, 65 to 80 percent of the fuel consumed in transport in the developing countries is used by road vehicles; of this, trucks consume 60 to 80 percent, indicating the need for special attention to this industry.

The scope for energy saving measures in road transport is significant, but they are less well known or developed than energy saving measures in industry. Experience in some countries shows that the training of truck and bus drivers and supervision of their driving performance can reduce their fuel consumption by 10 percent or more, while better vehicle maintenance—this includes regular tune-ups, maintenance of tire pressure, use of radial tires and wind deflectors, and prompt replacement of air filters—can save fuel 5 to 15 percent. Even larger savings are possible by improving the utilization of vehicles, mainly by reducing empty backhauls, and by using truck sizes and designs appropriate for the loads to be carried.

As in industry, it is useful to distinguish between large users (such as bus companies and operators of large truck fleets) and small users (individual owner/operators of cars, taxis, and trucks). In the case of large users, it is possible to audit the efficiency of vehicles and to train and monitor drivers and vehicle maintenance staff. Among small users, greater reliance has to be placed on information, promotion of awareness, innovative regulations, and the availability of equipment that can monitor and enhance energy efficiency. Appropriate energy pricing is vital, supplemented by a structure of vehicle taxes and import duties that encourages the use of fuel-efficient vehicles. In countries that manufacture vehicles, a special effort should be made to stimulate local producers to improve and publicize the fuel efficiency of their products.

Significant savings in road transport fuel are being realized in urban centers through traffic management designed to alleviate congestion. Schemes in Brazil, Singapore, Thailand, Venezuela and other countries have achieved savings of 5 to 15 percent through various restrictions, special bus lanes, or improved signalling; compared with their costs, such schemes yield large benefits.

There are opportunities for improved energy efficiency in other modes as well. Trains in North America and Europe have been modified to consume 3 to 10 percent less diesel fuel; ships and aircraft can also be made more fuel efficient, initially through improved maintenance and operation, and subsequently through replacement by more fuel-efficient models. In certain situations, alcohol can replace gasoline in road vehicles (as in Brazil), railways can be electrified (India is an example), and some road vehicles can be made to run on compressed natural gas (as tried in Bangladesh) and liquefied petroleum gas (for example, in Thailand).

Households

The household sector accounts for a small proportion of the total commercial energy used in developing countries—typically less than 10 percent in the poorer countries and between 10 and 20 percent in the middle income countries. However, these statistics are somewhat misleading because they exclude fuelwood, which is the principal fuel for households in developing countries. If fuelwood and agricultural and animal residues are included in the national energy balance, the household sector is the largest energy user in most developing countries, accounting for almost half of the total energy used in most of these countries and up to 90 percent in some of them (for example, Burundi, Malawi, Nepal, and Rwanda).

Because of the limited use of commercial energy in the household sector, coupled with the tendency of goverments to hold down the costs of kerosene, electricity, and indigenously produced coal, higher international energy prices have had a limited effect on the direct energy costs incurred by households. Nevertheless, the economic value of household energy consumption is substantial in some countries, particularly those in temperate zones (China, Republic of Korea, and Turkey, for example) and considerable scope exists for improvements in home heating and cooling equipment, insulation, and substitution by more economical sources (such as coal, biogas, and solar devices).

The situation for fuelwood, which is used principally for cooking, is different. Despite its increasing scarcity and, therefore, higher prices and increased gathering time, wood is still burned very inefficiently in the developing world. When food is cooked over an open fire, as is common in many developing countries, only about 5 to 10 percent of its energy content is typically used. Many traditional stoves are not much more efficient. Laboratory and field tests show that wood requirements can be at least halved through the introduction of improved stoves. Considerable work has been done in many developing countries in designing a first generation of more efficient woodstoves and in research and demonstration programs aimed at promoting them. However, it has been more difficult than envisaged to design stoves which are simultaneously cheap, much more efficient, and made of materials that can easily be obtained in poor areas. Second, people have been reluctant to use new stoves which require a change in cooking habits, or which do not provide some of the ancillary benefits of traditional open fires (such as space heating, lighting, or protection against insects), or where fuelwood savings are not perceived as important enough to warrant the cost of the stoves. Finally, many of these programs have been hampered by a weak and uncoordinated institutional framework and by the absence of a clearly defined strategy for action.

Despite the generally disappointing experience so far with this initial series, improved woodstoves should be the main focus of any energy demand management strategy for the household sector in most developing countries. Realizing their potential will require greater support for work which has already started on a second generation of stove programs characterized by the adoption of a more systematic approach to stove design and promotion, and a reorientation of focus towards fuelwood users who are most conscious of the fuelwood problem—particularly urban and semiurban households. For these households, wood is already a commercial energy source and cash savings could provide them with a strong incentive for buying a stove which reduces wood consumption. An increased focus on urban wood users will probably also lead to greater emphasis on promoting fabricated metal or ceramic stoves. Such stoves have already been successfully introduced for charcoal use in a few countries (Burundi, Kenya, and Thailand) and their replication in others merits attention.

Commercial and Institutional Buildings

The commercial sector is becoming an increasingly important user of energy in the middle income developing countries and in some small countries where air conditioning—particularly of hotels for tourists—accounts for a significant proportion of electricity demand. In these situations, the scope for energy savings may be sizable. In existing buildings, savings of up to 25 percent can be achieved through better energy management, improved control and monitoring systems, and minor retrofitting investment. Improved standards and regulations for the design of new buildings can reduce their heating and cooling requirements to 50 percent of those of buildings designed as recently as ten years ago. In some countries, solar collectors can economically displace conventional fuels for heating water in hotels and other institutional buildings. Substantial advances have been made in these areas in industrialized countries and a variety of new techniques, equipment, and materials have been developed. Governments can help in this regard by providing information on new designs to the local architectural community, by revising the codes and regulations governing new buildings, building equipment and materials, and by stimulating audit programs and the production or import of energy management technology and know-how for the building sector.

Table 2.2. *Electric Power Lost in Transmission and Distribution Systems in Developing Countries, 1980*

Losses as percentage of generation[a]	*Percentage of countries*[b]
0–10	17
11–15	33
16–20	21
21–30	21
31–40	8

a. Includes technical losses and unmetered consumption.
b. Sample of 76 developing countries.
Source: World Bank.

Electric Power

Energy is consumed in the conversion of primary energy into electricity and in its distribution to customers. A review of available data for 76 developing countries shows that in half of them, the power transmission and distribution system "loses" 15 percent of the electricity generated (see Table 2.2). These figures include both technical losses and unmetered consumption. All types of losses cause financial difficulties for the utility and require corrective action, but technical losses represent economic losses for the country. It is expensive to reduce losses, however, so the lowest possible losses are not necessarily the most economic. Their optimal level depends on the load and network characteristics of the system and on the marginal costs of supply. Research by the World Bank indicates that under normal circumstances, transmission and distribution losses should be between 4 and 8 percent of total annual generation and between 7 and 12 percent of peak power.[1] Thus, the typical power system in de-

1. The World Bank. *Energy Efficiency: Optimization of Electric Power Distribution System Losses*. Energy Department Paper No. 6 (Washington, D.C.: July 1982).

veloping countries needs to reduce its losses by one-third to one-half. Many of the countries with higher loss rates also have low per-capita incomes and high energy costs and can least tolerate this economic waste.

Reducing technical losses in transmission and distribution requires two sets of actions.

- Determination of optimal loss levels and design standards for existing and new facilities.
- Investments in loss-reduction facilities, including reactive power control with capacitors, reconductoring, addition of feeders, higher capacity transformers, and load switching equipment.

Recently, general budget constraints on public investments have induced utilities to defer reinforcing their distribution systems because, for a year or two, doing so has less effect on the power system's capability than failure to increase generating capacity. The evidence shows, however, that it can be nearly three times cheaper to save one kilowatt (kW) of electricity by improving the distribution system than to produce an additional kW from new generating equipment. Looked at another way, the reduction of the distribution loss rate from 10 to 5 percent could be equivalent to one year's demand growth. Programs to reduce power system losses are an increasingly important feature of the Bank's work in the electricity subsector (see Box 2.3).

The scope for reducing generation losses in an electric power system depends primarily on the marginal costs of generation, the standards of design, maintenance and management, and occasional possibilities for retrofitting thermal stations. Countries, such as China and India, where thermal generation produces more than 80 percent and 50 percent respectively of the total power supplied, have considerable scope for such improvements; energy audits of thermal generating plants should be carried out to determine what should be done and how. One major necessity is to restore the efficiency of existing units to their design level, through improved management. A second necessity is to ensure that the design of new plants is economically optimal and that it considers future cost structures and levels.

Another means of saving energy in the power subsector is to take advantage of the complementarity between various energy demands. For example, a convenient complementarity can exist between the production of power and process heat in the medium temperature range (200°C to 400°C) needed for many industrial processes. Waste heat from the utility can be used by industry located close by. Cogeneration schemes involve the production of electricity by industry,

Box 2.3. *Reducing Losses in Power Distribution*

The rise in the cost of generating electricity has made it economic to increase investments in capacitors and in oversized distribution equipment in order to reduce losses in the distribution system. Investments to improve efficiency are justified in most power systems in developing countries, but they are frequently not made because they do not qualify as "projects" in the usual sense and, therefore, do not appear in the project portfolios of governments seeking financing. Improvements in the efficiency of power systems have been identified as necessary in most of the country energy assessments that have been completed under the joint UNDP/World Bank program. In response to these findings, the UNDP agreed to fund an initial program to identify power system efficiency projects in developing countries. This program uses a computer-based methodology, developed under a World Bank research project, to determine the optimal level of losses and identify how actual technical losses can be reduced to this level.

A pilot study of Zimbabwe's power system, which is relatively efficient, revealed significant and unexpected opportunities for efficiency improvements—for example, an expenditure of a million dollars on capacitors would have a payback period of less than two years. Similar findings are expected in Panama and Sri Lanka, whose systems are also being studied under the UNDP grant. These studies would help identify and initiate the preparation of training, rehabilitation, and investment projects for which financing could be obtained from bilateral and multilateral sources including, but not limited to, the World Bank. Measures to reduce power losses are expected to be implemented in many more countries under the Bank's power projects and under the overall Energy Sector Management Program (see Box 4.4).

in excess of its own needs, for sale to the utility. This type of arrangement is likely to be economic when the industrial process requires both electricity and heat, with less of the former than the latter. This kind of cogeneration is even more attractive to energy users with sizable amounts of waste fuels, such as bagasse, which is plentiful in many developing countries (see Box 3.3).

In large systems, more attention to load management is warranted. Refineries, cement factories, steel and chemical industries have some flexibility in dramatically cutting their demand during peak hours or during the whole day. Also, wherever electricity has been used to substitute for fossil fuels in thermal uses, there remain idle furnaces which the utility could use to enable it to delay the installation of new peaking capacity.

In order to thrive, load management schemes require marketing and tariff structures based on economic costs. They also call for a small amount of metering and monitoring equipment which technological progress has made increasingly applicable in developing countries. The World Bank is complementing its traditional commitment to marginal costing studies by supporting system instrumentation to reduce the necessary size of peak capacity.

Conclusions

The experience of the last few years has confirmed that considerable potential exists for reducing the energy intensity of economic activity and growth in developing countries. Further, there is scope for reducing the total costs of energy used in the economy, by substituting cheaper forms of energy for more expensive ones in both existing and new facilities. The exploitation of this potential depends crucially on the commitment of governments, institutions, and enterprises to improving the efficiency of energy use. Few developing countries have given sufficient emphasis to this area, and in nearly all of these countries, demand management efforts, including policy and institutional changes and the allocation of investment, deserve much higher priority.

Effective demand management programs need to be selective in their focus, but they should normally include the following features:

- Identifying and realizing the substantial energy savings that can accrue from improving the efficiency of energy use in large energy-intensive industrial plants, in large public and private transport enterprises (including railways), industrial users of fuelwood, and the power sector; these can be low-cost savings through better energy management, training, or maintenance, as well as larger savings through investments in heat recovery facilities and modifications to equipment and processes.
- Developing an institutional and policy framework to provide smaller energy users in all sectors with the information, incentives, and know-how to improve their energy efficiency; this includes appropriate pricing policies, fostering the availability of energy-efficient equipment, special financing arrangements, provision of information, and research, development, and promotion efforts.

In the broader economic sense, a whole range of strategic and policy choices affect the future pattern and growth of energy demand in each country. The increased cost of energy requires more critical review than is customary of the expansion plans of energy-intensive industries; of policies affecting the choice of transport modes; the design of commercial and insitutional buildings; urbanization patterns; sources of primary energy for electric power; and the design and operation of petroleum refining facilities. The management issues posed by the links between the energy sector and the rest of the economy are discussed in Chapter 4.

3. Energy Supply Prospects and Issues

Since 1973, all countries have made a major effort to expand their energy production. Most developing countries quickly recognized that higher international oil prices made it worthwhile to exploit and develop indigenous energy resources that had previously been uneconomic. Consequently, stronger programs to increase domestic energy supply became an essential feature of adjustment to the new international energy situation. In the past, developing countries' commercial energy consumption has grown much faster than production (5.9 *versus* 3.6 percent per year respectively in 1970–80). In 1980–95, however, through a combination of demand management and supply development, the gap could be almost eliminated; as a group, developing countries' production of commercial energy is projected to rise at over 4 percent a year.

The projections summarized in Table 3.1 show a particularly high rate of growth of energy production in the oil importing developing countries. Their indigenous energy production is forecast to grow at 6.3 percent a year between 1980 and 1995, with relatively high rates of growth in gas and primary electricity.

These projections are ambitious in two senses. First, it is by no means certain that sufficient financial resources will be mobilized to implement the investment projects that will be required. And second, even if adequate finances were available, production increases of this magnitude will require a high degree of commitment to energy sector development on the part of national policymakers and the early resolution of a variety of specific issues and constraints affecting the development of each major energy resource. However, it is equally important to emphasize that the projections are both technically feasible and economically viable.

The projections were prepared for developing countries individually, considering their overall energy demand and economic growth prospects. The average economic growth rate associated with the projections is 4.8 percent a year over the 1980–95 period but, for the major commercial energy users, the energy projections were derived from individual economic growth forecasts prepared as part of the Bank's overall country economic work. The oil production projections assume a sustained improvement of effort over the next two decades, but no drastic changes in the pace of exploration. Among existing producers, it is assumed that past rates of additions to reserves will increase somewhat and that ongoing secondary and enhanced oil recovery projects will yield better results, where this seems feasible, while the development of existing reserves is accelerated. About half of the increase in oil production is expected to come from already established, developed reserves and the balance from reserves yet to be developed in fields already discovered, or from new discoveries in known basins. The projections for natural gas and coal were prepared on the basis of known reserves, but they are well below the technical production potential because of logistic, economic, and market constraints. The forecasts for primary electricity production were prepared on the basis of the projected growth in electricity demand and utilities' expansion plans to meet that demand with the least-cost combination of generating facilities. Because of market or logistic constraints, the projected increase in primary electricity production is also substantially below

Table 3.1. *Commercial Primary Energy Production in Developing Countries, 1970–95*

	Million toe					Growth rates (percentage per year)		
	1970	*1980*	*1985*	*1990*	*1995*	*1970–80*	*1980–85*	*1985–95*
Oil importers								
Oil[a]	63	65	105	131	145	0.3	10.1	3.3
Coal	118	192	246	316	384	5.0	5.1	4.6
Natural gas	14	27	46	86	115	6.8	11.2	9.6
Primary electricity[b]	41	98	147	211	306	9.1	8.4	7.6
Total	236	382	544	744	950	4.9	7.3	5.7
All developing countries								
Oil[a]	774	919	1,069	1,243	1,375	1.7	3.1	2.5
Coal	294	502	598	736	886	5.5	3.6	4.0
Natural gas	52	116	185	309	424	8.4	9.8	8.6
Primary electricity[b]	56	130	197	279	396	8.8	8.7	7.2
Total[c]	1,176	1,667	2,049	2,567	3,081	3.6	4.2	4.2

a. Includes natural gas liquids and oil production from secondary recovery.

b. Includes hydro, nuclear, and geothermal electricity. See Table 3.8 for detailed projections of electricity supply by source.

c. Excludes alcohol, oil shale, tar sands, and other nonconventional primary energy sources which may add a small amount (up to 10 million toe or less than 0.5 percent) to developing country energy production by 1995 but where the prospects are too uncertain to quantify.

Sources: 1970 and 1980 figures are based on United Nations J series and the World Bank.

Oil Forecast: Prepared country-by-country on the basis of proven reserves published by *Oil and Gas Journal* (1950 to date), and of information on prospects for future oil exploration and development obtained from World Bank projects, published sources and government plans. Oil production profiles are determined by existing reserves, additions to reserves, and the reserve to production ratio.

Natural Gas Forecast: Prepared country-by-country on the basis of published estimates of proven reserves, and estimates of domestic demand obtained from World Bank sector and project work, published sources, government plans, and existing export contracts.

Coal Forecast: Based on project-by-project assessment of likely coal production and project viability, reflecting the countries' overall energy demand and prospects for domestic coal use and for exports. Coal production is limited by lack of preinvestment work, manpower, institutional, and capital constraints.

Primary Electricity Forecast: Prepared on the basis of country-by-country forecasts for total electricity supply and the least-cost generation mix to meet that supply. Total electricity supply forecasts were based on national power development plans, adjusted to account for current World Bank forecasts of GDP growth and for limitations in the availability of individual fuels (given by economic or physical constraints).

the resource potential in a large number of countries.

This chapter focuses on issues that are relevant to the various subsectors of energy. Some indication is also given of the role played by the Bank in helping developing countries to accelerate their energy resource development.

Petroleum

It is now widely accepted that there are a reasonable number of economically justifiable petroleum prospects in the developing countries.[1] But, despite the rise in the price of oil, over the past decade there has been little increase in exploration activity in most developing countries. As shown in Table 3.2, while exploration in the oil importing developing countries (OIDCs) as a group expanded between 1972 and 1980, it did not increase relative to worldwide activity. Moreover, virtually all of the increase in activity has been concentrated in the petroleum producing OIDCs and the share of nonproducing importing countries in total drilling has declined considerably since 1972. The expanded programs of national oil companies in three countries—Argentina, Brazil, and India—alone account for almost 60 percent of the increase in exploratory drilling in all oil importing developing countries over the period (see Figure 3.1).

While caution is always required in assessing whether the pace and distribution of petroleum exploration are appropriate, recent trends ap-

1. See, for example, *Third World Petroleum Development: A Statement of Principles*, National Petroleum Council, USA, 1982.

Table 3.2. *Exploration Activity in Oil Importing Developing Countries, 1972–80*

	1972	*1974*	*1976*	*1978*	*1980*
Seismic activity (thousands of line-km)					
Producing countries	n.a.	69	128	197	238
Nonproducing countries	n.a.	61	39	55	61
Total	n.a.	130	167	252	299
Exploratory wells					
Producing countries	338	380	424	431	497
Nonproducing countries	35	39	47	38	36
Total	373	419	471	469	533
of which:					
Majors	64	60	78	71	106
Foreign national oil companies	16	14	20	19	22
Foreign independents	11	14	21	34	9
Domestic independents	8	11	3	10	17
Subtotal	99	99	122	134	154
National oil companies	274	320	349	335	379
Argentina, Brazil, and India	(183)	(242)	(235)	(223)	(275)
Others	(91)	(78)	(114)	(112)	(104)
Total number of wells worldwide	10,437	11,591	12,808	15,207	17,290
Number of wells in OIDCs as percentage of world total	3.6	3.6	3.6	3.1	3.1

n.a. Not available.
Source: World Bank estimates.

pear less than desirable. The exploration results summarized in Table 3.3 at least partly reflect these trends.[2] Gross additions to oil reserves in the OIDCs have fallen short of production rates and are a small fraction of the increases elsewhere. Moreover, the record is worse than shown in the Table, since oil reserve additions were also concentrated in very few countries. This pattern reflects a combination of circumstances unfavorable to the OIDCs, notably the competition of already-producing areas (particularly in the United States and Canada which have attracted a very large share of the growth in exploration) and the time taken by governments to adjust their legislative and contractual frameworks to new circumstances and for the petroleum industry to adjust to changes in the political environment.

Prospects and Strategies

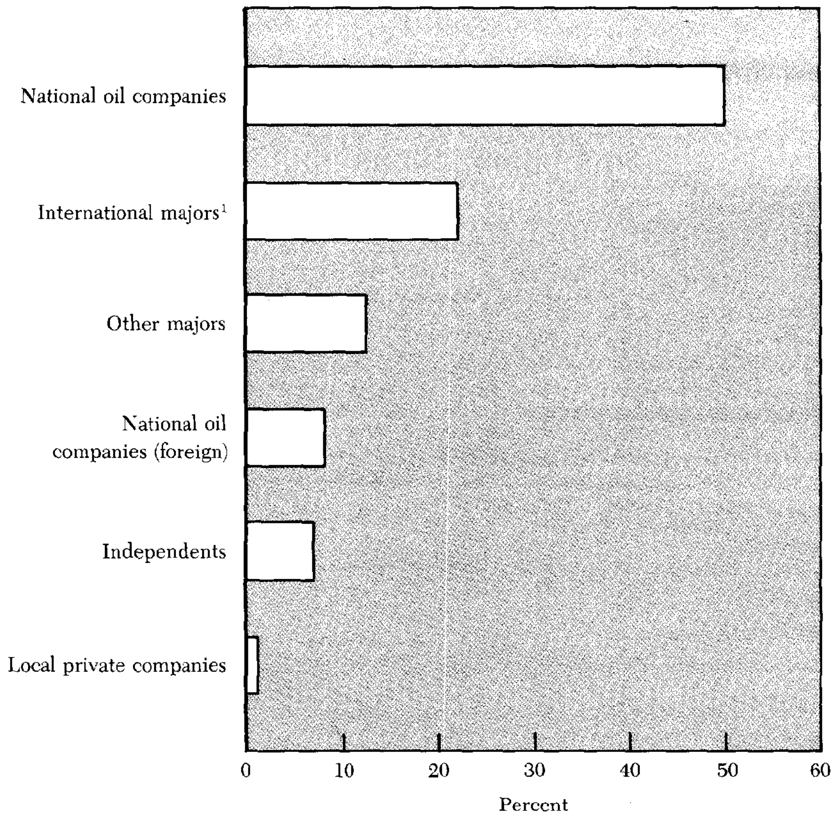
These recent trends highlight the need to accelerate the pace of exploration in the developing countries, particularly in the oil importers. To bring about such an acceleration will require closer collaboration between international oil companies (IOCs) and developing countries, purposive action by developing countries to improve the policies and legislation affecting petroleum exploitation, and measures to increase the efficiency of national oil companies.

For host governments, the principal task is to formulate a clear and realistic petroleum development strategy which would set out the contribution that could be made by various sources of technological know-how and finance. These sources include domestic and international private oil companies, commercial and official credit agencies, and the national oil company (NOC). For example, key decisions must be taken on the division of labor between IOCs and a national oil company, on alternative mechanisms for collaboration (such as joint ventures, service contracts, and so forth) and on how best to promote the local acquisition of relevant technical and managerial skills.

To formulate and manage a petroleum sector strategy effectively, most developing countries need to strengthen their capabilities in at least three areas:

2. "Partly" because causality undoubtedly runs two ways: results are poor because activity is limited and insufficiently diverse; at the same time, the pattern of activity is partly attributable to poor results.

Figure 3.1. *Average Data for Exploration in 90 Developing Countries, 1972–81*



1. British Petroleum, Chevron, Exxon, Gulf, Mobil, Shell, and Texaco.

- *Promotion.* Public agencies need to be able to identify "promotable" areas, package and present related technical data for foreign oil companies, explain the applicable legislative and contractual framework, and conduct publicity campaigns and negotiations.
- *Monitoring of activity.* Public agencies need technical skills to represent the national interest adequately, for example to review or react to IOC exploration programs and to identify specific opportunities to be followed up by nationals as the IOC's work progresses.
- *Administration and management.* Countries must be able to maintain and retrieve reports and information, deal expeditiously with requests for a wide range of approvals, audit IOCs' financial accounts and maintain internal accounts. When public petroleum agencies become fully operational, they must acquire associated corporate skills in organization, capital budgeting, project control, and so forth.

Nearly all Bank loans in petroleum have assisted the borrowing country in formulating petroleum development strategies. For most of the countries covered by the Bank's oil and gas program, promotion is the most urgent requirement. Bank assistance has been particularly valuable to countries in the development of an exploration plan or strategy, in larger countries (notably India, Pakistan, Turkey, and Peru), as well as smaller countries with less petroleum experience (Equatorial Guinea, Jamaica, Liberia, and Madagascar) (see Box 3.1). While the Bank's program has emphasized promotion, it has also included training to prepare NOCs to monitor

Table 3.3. *Changes in Oil and Gas Reserves in Developing Countries, 1973–81*
(billion barrels of oil equivalent)

	Oil importing developing countries	*All developing countries*
Reserves, year end 1972		
Oil	12.4	488.8
Gas	7.3	170.0
Total	19.7	658.8
Gross additions to reserves, 1973–81		
Oil	4.9	177.3
Gas	19.2	121.6
Total	24.1	298.9
Cumulative production, 1973–81		
Oil	5.4	119.0
Gas	3.4	9.2
Total	8.8	128.2
Reserves, year end 1981		
Oil	11.9	547.1
Gas	23.1	282.4
Total	35.0	829.5

Source: World Bank estimates based on information from *Oil and Gas Journal* and *British Petroleum Statistical Review*.

and interpret the results of exploration activity and, in certain cases, engage directly in exploration when the priorities of the international industry do not match the priorities of the country and where the NOCs have the capacity to do so.

Role of International Oil Companies

International oil companies (IOCs) have made major contributions to the development of petroleum resources in developing countries, not simply in their share of exploration (roughly 25 percent of developing countries' annual exploratory wells), but in the success of their exploration and development programs. They are major sources of risk capital and they bring a wealth of management experience and up-to-date technological expertise to projects they are involved in, thereby facilitating the mobilization of debt capital as well. And, no less important, they bring a variety of ideas and approaches to the exploration and development process which should be especially prized in many developing countries where exploration has not yet been successful. Whether or not these companies invest in exploration in developing countries depends to a large extent on actions by the governments of those countries. Studies commissioned by the World Bank and others have identified several common deterrents to IOC exploration in the developing countries. These include:

- The companies' perception of the geological prospectivity of developing countries.
- Legislative and contractual frameworks which limit access to acreage or the right to export petroleum, or fail to provide adequate financial incentives.
- Unstable economic and political conditions.
- Cash constraints.

Geological prospectivity is fundamental to international oil companies' assessment of new exploration ventures, especially in oil importing developing countries where less information is available. While no country can change its geology, it can facilitate access to existing data and, in some cases, generate new information through low-risk and low-cost investments in the orderly compilation of existing geological data and in the limited acquisition of new data (aeromagnetic or gravity surveys, reconnaissance seismic surveys, and even, in some limited cases, drilling).

Such investments improve the government's knowledge of a country's petroleum prospects and enable it to design a strategy to attract interest from a wider spectrum of IOCs, rather than waiting for a company to make a proposal. Good information would, at a minimum, reduce IOCs' perception of technical risk and, hopefully, help stimulate new interest in exploration by identifying new exploration strategies or concepts. Even if they fail to do the latter, these programs may be justified: national policy planning will gain from a better understanding of the country's petroleum potential and prospects may be identified which, though of no interest to the international industry, are of economic merit to the country.

Loans to support such improvements in geological data are a feature of the World Bank's petroleum program. Guinea-Bissau and the Philippines provide examples. Past programs mounted

Box 3.1. *The World Bank's Exploration Promotion Projects in Oil and Gas*

The main purpose of the Bank's exploration promotion projects for petroleum has been to accelerate the competitive offering of new acreage to the international petroleum industry on reasonable terms. To date, exploration promotion has focused largely on developing countries that do not produce oil. Promotion projects contain one or more of the following elements:

- Preparation of promotional data relying heavily on the orderly compilation of existing data, but also occasionally financing the limited acquisition of new data through aeromagnetic or gravity surveys, or reconnaissance seismic drilling where necessary.
- Technical assistance and training for national entities in petroleum geology or geophysics and engineering, economics, accounting, and petroleum law.
- Expert advice on petroleum laws, contracts, and taxes from consultants hired by the national agency who also assist in the promotion and subsequent negotiation of contracts with the international industry.
- The reduction of political risks through a variety of arrangements ensuring Bank "presence" during the exploration and/or development phases of foreign contractor activity.
- The assessment of past single-well discoveries which could be profitable under current economic conditions.

Exploration promotion features in close to half the Bank's oil and gas projects approved to date, though it amounts to only 5 percent of the cost of this program. The strong appeal of exploration promotion projects lies in their potentially large multiplier effect. In Madagascar—the first country to go through the full cycle of project definition, promotion, and negotiation of contracts—$2 million in Bank credits were disbursed within 18 months, while the total commitments made with four international companies for exploration amounted to more than $70 million. Other countries where promotion projects are well advanced and seem likely to result in new commitments, despite the unfavorable exploration climate, include Equatorial Guinea, Guinea-Bissau, Kenya, Liberia, and Somalia.

The Bank's emphasis on exploration promotion will continue to grow over the next several years. Conventional promotion projects in smaller countries with little or no petroleum activity remain to be completed, and in many of the countries concerned, follow-up promotion may be justified. New possibilities for promotion projects lie in producing countries in the field of gas exploration. Significant exploration opportunities in larger petroleum producing countries are being set aside or postponed, to the host countries' disadvantage, by national policies which unreasonably restrict international oil companies' access to acreage. Bank dialogue with these countries has increasingly stressed the benefits of an open-door policy. The Bank has already identified opportunities for promoting gas exploration and development for internal markets and is working with host country governments to remove policy-related impediments, notably in the pricing area, to new foreign investment.

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by IOCs in Guinea-Bissau had proved unsuccessful and all acreage had been abandoned. The Bank agreed to finance Guinea-Bissau's share of a new offshore seismic campaign with remaining financing put up by the seismic operator on a speculative basis. The data produced, integrated with previously acquired data, were then sold to industry. The proceeds covered the cost of acquisition and the number of companies expressing serious interest in the country increased from two to twelve, with contract negotiations underway. In the Philippines, a recently approved Bank project will finance a phased seismic and drilling program over areas which international companies had identified as possibly interesting to the Philippines though not to themselves on account of the probable small size of any discovery. The data acquired will, nevertheless, be made available to industry as work proceeds.

The legislative and contractual framework governing petroleum exploration and production is at least as important to the IOCs as the geological potential or the cost of exploration when it comes to deciding on new ventures. It is, therefore, important that when host governments have decided to encourage international companies, they should act to minimize administrative and physical obstacles to these companies' efficient operation. The contractual terms offered by the host government will form the framework within which an IOC will evaluate the risk of a proposed venture as well as its expected return. Thus, they should provide reasonable answers to the concerns of such companies (division and repatriation of profits, eligibility for foreign tax credits,[3]

3. Certain provisions of tax law in the United States significantly reduce the profitability of international exploration for U.S. companies.

right to explore and develop, as well as control of operations and reasonable arbitration procedures). While the Bank has not been directly involved in contract negotiations, its familiarity with many contracts in different countries has made it an objective source of advice on differences of opinion between oil companies and host governments.

IOCs are probably prepared to step up exploration in several developing countries that presently restrict access to prospective acreage, and particularly in those which are relatively large producers with established national oil companies (for example, Brazil, Ecuador, India, Peru, and Turkey). Policies that unduly restrict access to acreage can be disadvantageous to the host country. Where they result in even modest delays (one to two years) or cost increases (10 to 20 percent) *versus* the alternative of inviting immediate IOC participation, all the financial benefits of having refused to share the benefits of successful exploration with the IOCs are likely to be lost. And, of course, such policies shift all exploration risk to the host country.

The World Bank has increasingly emphasized the benefits of an open-door policy. India, Pakistan, and Turkey are among those countries which have recently taken steps to release acreage held by the national oil company to international industry, with some encouraging preliminary results.

Concern for the right to export crude oil may limit IOCs' interest in exploration where prospectivity and the size of the host country's internal market for petroleum make exportation very unlikely. Integrated IOCs with sizable downstream demands for petroleum, or foreign national companies with "briefs" to secure crude oil supplies for their home countries, are likely to place a premium on offshore access to production. Other companies may value the right to export because it provides assurance of a minimum access to foreign exchange. Though an oil importing country can hardly promise to export oil, increased attention might be paid to ensuring that contracts allow any revenues from domestic sales to be converted expeditiously into foreign exchange; this is of particular importance because it is virtually impossible to mobilize financing on a nonrecourse basis when export revenues are not available to secure debt repayment.

Several countries have recently made conditions more attractive to IOCs. Peru and Turkey have improved the contractual terms offered. Equatorial Guinea and Liberia have established a new legislative framework whereby petroleum exploration contracts can provide for incentives attractive to IOCs. The Bank has consistently advised governments to be pragmatic, making their acreage competitive while ensuring that returns would be shared satisfactorily under different circumstances. Most of the Bank's exploration promotion projects provide for experts to advise the government on petroleum laws, contracts and negotiations, and help build mutual confidence between the IOC and the host country. The Bank has also concerned itself directly with some of the more significant issues in these areas and developed or promoted new alternatives. For example, it has encouraged the consideration of fiscal systems which, in accordance with a predetermined or negotiated formula, adjust government revenues in direct relation to the IOC's actual profits as measured by its discounted cashflow return on investment.

IOCs are, of course, not only concerned about the investment framework at a particular point in time but also in its likely stability over 10–15 years. Sometimes assurances of such stability are written into the contracts companies make with governments. Among the other options available is the maintenance of a World Bank financial presence during the exploration and/or development phases.

The Bank has developed several instruments to ensure its presence during exploration, mainly to limit private investors' perceptions of political risk. Discussions with IOCs suggest a good deal of interest in such arrangements, although so far there have been few projects in which Bank participation is specifically intended to stabilize a government-investor relationship. One example is the recently approved petroleum project in the Ivory Coast; the Bank also played this role in exploration projects in Pakistan although these did not involve direct Bank financing. The Bank may do more in this area as more countries receive international oil companies for the first time and as, hopefully, smaller oil companies consider increasing their exploration in developing countries.

Any new incentives to IOC exploration should be widely publicized by the host country. Most larger countries are accustomed to mounting the required promotional efforts and the larger IOCs are generally well equipped to keep abreast of new developments. But for smaller countries, and with smaller companies, more promotion is probably required.

Promotional work is a feature of close to half the petroleum loans approved by the Bank to date. It may be that, with enough information, middle-sized or smaller oil firms could be attracted to invest in developing countries. Many of the projects identified in these countries may, under the right circumstances (for example, with a World Bank presence), be better suited to the independent oil companies than to the larger internationals. Independents may be willing to look at smaller-scale projects (such as the appraisal of one- or two-well discoveries); they may be unconcerned about physical access to production; or they may be prepared to enter into less conventional arrangements such as management contracts.

The Bank has found that the issues outlined in the preceding paragraphs can be addressed constructively and resolved. Projects that have completed the first promotion cycle have positive results and, as indicated earlier, interest in ongoing projects is strong despite the less-than-favorable market conditions. Shortages of cash have, however, become an increasingly serious constraint on investments by IOCs in exploration and production. More consideration might usefully be given either to contracts which involve these companies in exploration and production in return for a management fee plus a performance incentive (so that the company need advance no capital) or to the government's direct participation in exploration. Though in certain cases such forms of contract may be the only way to maintain the momentum of exploration, their use requires caution, since they shift the burden of risk and finance on to the host country.

As the reserve additions shown in Table 3.3 suggest, a significant number of developing countries are gas prone. IOCs have shown little interest in exploring for gas except in the very few cases where actual or possible export-scale projects have been identified (Algeria, Cameroon, Indonesia, and Nigeria). Their reservations about developing gas supplies for domestic consumption stem from the lack of transmission or distribution facilities, from gas pricing practices, and from the difficulty of converting the proceeds from domestic sales into foreign exchange. While gas is of little interest to IOCs, it can help the country materially to reduce energy imports. Given this difference in perspective, any exploration of gas-prone areas will probably have to be done by national oil companies. Much could be done to accelerate the development of gas resources which have already been discovered and to encourage IOCs to explore for gas in developing countries. The Bank can, and has, already played a very important role in this field in a growing number of countries, including Bolivia, Egypt, Morocco, Pakistan, and Thailand. This role may increase in the future as companies are trying in a number of cases to associate the host government in the appraisal and development of gas resources, partly because of shortages of funds, and partly because gas development projects for export or for domestic use are much more closely linked to government policies than oil projects (as in Tanzania and the Sudan).

Role of National Oil Companies

National oil companies (NOCs) are an arm of the government in managing the petroleum sector. They vary widely, from the small units in charge of distribution in many African countries to a fully integrated oil company in Brazil. National oil companies serve two important functions. First, they can assist the government in developing a petroleum sector strategy and in managing the activities of the private sector in petroleum exploration and development. However, it is important to ensure that the policies of the national oil company do not become *de facto* the country's petroleum development policy and that there is a staff capability at the national level to review and monitor the work of the NOCs. The second function of NOCs is to carry out an exploration and development program, either alone or in association with private companies, where direct public sector execution of such a program is an appropriate part of the country's petroleum development strategy.

It is quite common for exploration to be worthwhile from a country's point of view and yet of no interest to IOCs; this could be the case where:

- Host country and IOC priorities differ markedly. A developing country facing crippling petroleum import bills and few short-term options is likely to assign a much higher priority to accelerating the pace and/or broadening the scope of exploration (in that country) than is an IOC facing a wide range of possible projects around the world. The IOC has to allocate its own limited technical and managerial talent to those projects which promise it the highest returns. A project being promoted by a country may have economic merit but simply not rank as high as projects elsewhere on the IOC's list. The IOC can afford to wait; it may even feel constrained to wait by cashflow considerations, particularly in the current environment.
- Pre-tax economics justify proceeding, but post-tax economics do not. Obviously, a country appropriately calculates benefits and costs on a pretax basis; an IOC on a posttax basis. Even under generous fiscal provisions (for tax plus other payments to government), there may be as much as \$5 to \$8 per barrel difference between the anticipated project cost which will cause an IOC to abandon its interest in exploration and the cost at which the economic benefit to the host country vanishes.[4]
- Exploration promises larger benefits to the country than those which would accrue to an individual IOC investor, for example, by making adjacent acreage not leased by that particular company, more attractive to other investors.
- IOC interest has been constrained by strategic rather than strictly economic considerations; for example, a lack of interest in gas, or in developing supplies that are unlikely to be exportable.

In the Bank's experience, such circumstances create a large number of specific opportunities for direct public sector sponsorship of exploration. A cautious approach should be adopted in pursuing such opportunities, for example, by concentrating first on ventures where technical and commercial risks are low, for which national competence exists, or for which experts can be contracted on reasonable terms.

The Bank has approved eight projects for exploratory drilling by national oil companies, targeted at specific opportunities rather than as part of a broad exploration program. The Philippines project follows the prescription implied by the two preceding paragraphs: clear potential for benefit by the country; limited risk (a phased exploration program over an area with recognized petroleum potential); absence of IOC interest; a national oil company with demonstrated competence; and a commitment to contracting expertise from international oil companies as appropriate. Projects in other countries repeat the pattern. In Bolivia, for example, the Bank sponsored delineation (rather than wildcat) drilling which demonstrated that gas reserves were sufficient to justify an export pipeline to Brazil. As a result, IOCs present in Bolivia but reluctant to invest further in exploring gas-prone areas began to express new interest as their prospects of participating in an export project (a condition of the Bank loan) grew brighter. In Tanzania, Bank credits have financed the appraisal of a known offshore gas structure abandoned by the industry as too small to be of commercial interest. The Bank-sponsored program, implemented by internationally recognized exploration and drilling contractors in cooperation with the national oil company, has proved the presence of sizable reserves. Options for local use of the gas are now at an advanced stage of review. At the same time, the government has pursued an active exploration promotion program which has resulted in the extension of an existing contract and the signing of three new ones. Similar projects are underway in Egypt, India, Jamaica, Morocco, Portugal, and Turkey and more are likely to be undertaken.

Given the strategic importance of the petroleum sector, some countries wish to develop their own capability to avoid exclusive dependence on foreign capital and know-how. Given the very large capital requirements and special technol-

4. 1982 dollars. Future revenues and costs discounted at 10 percent.

ogy of the petroleum industry, practically no oil importing developing country has developed even a fledgling capability in the private sector. Hence, the role of the state-owned oil companies has grown, especially in larger developing countries with established petroleum sectors. Where national oil companies are sufficiently technically competent and financially independent to undertake complex capital-intensive exploration programs (as they are, for example, in Argentina, Brazil, India, Peru, and Yugoslavia), the Bank will consider supporting their efforts. Bank presence contributes to improving project design and implementation as well as to strengthening the managerial capacity of these institutions. A recently approved loan to India's national oil company will finance a part of its exploration program in a prospective offshore basin.

The Bank's dialogue with national authorities is a very important part of loan preparation. The dialogue focuses not simply on the specific project, but on exploration strategies for the country as a whole. Typically, this involves matching exploration targets with the financial and human resources available to the national entity, discussing acceptable levels of national risk, and considering the role of IOCs and international oil service companies. Typically, too, considerable time is spent discussing how to make the national company more effective, not only in those programs which it undertakes alone, but also in those which it undertakes jointly with the international industry.

Development

Moving from petroleum exploration to development is a continuous process whereby additional data are acquired and analyzed, leading to decisions on whether to commit additional expenditures. A distinction between these phases is commonly used in the industry, however, referring mainly to the mode of their financing.

In most producing OIDCs, petroleum is produced from a variety of fields, some at an early stage of development, some mature, and some virtually exhausted. Experience has shown that problems are most likely to occur at the early stage of production and when producing fields start to decline. The process of appraising a discovery, until the operator can finally decide on its commercial worth, can take months and possibly years, depending on the nature of the discovery (oil/gas), its location (onshore/offshore), and the terms of the exploration/production agreement. This is the time where the relationship between the IOC and the host government is most vulnerable, or when inefficient decision making may cause an interesting discovery to be abandoned. At this stage, investments in appraisal delineation drilling, reservoir studies, and assessment are critical, but the willingness of IOCs to undertake them depends on their perception of future profitability, while NOCs, even where they have the technical skills, may be constrained by the availability of funds. During this phase, a project may be delayed by inadequate information, slow decision making, or lack of alternatives to contract terms which did not foresee the situation.

Delays may also be caused by difficulties in mobilizing finance for the large investments that are generally necessary at this stage, particularly for offshore development. Early in the development stage, reserve estimates are often too uncertain to be used as a basis for raising project finance. While an IOC may be able to raise its share of finance from commercial sources supported initially by a corporate guarantee, a government may not have this option. Unless resources can be mobilized from other sources such as the World Bank, the government's only alternative may be to reduce its participation and, thus, its benefits.

The evaluation/delineation process may result in a discovery which is economic for a country but not for an IOC. This may be because the field is too small to become economic for the IOC under any reasonable terms that could be negotiated, or because the discovery is some distance from the market or export points, so that the company wishes to accumulate several more discoveries before deciding to proceed with a full evaluation (Chad, Niger, and the Sudan are examples). A government may wish to appraise and develop such a discovery at its own risk. This situation is often contemplated in petroleum agreements which provide for further appraisal and development of such a discovery at the government's "sole risk". To pursue this option, a government would require funds urgently for appraisal drilling until the discovery is proved sufficiently economic for finances to be mobilized commercially.

The World Bank can help significantly to accelerate the appraisal and development of discoveries made by national oil companies by providing enough funds and continuity to move smoothly from the "wildcat" phase to the evaluation phase. In Morocco, for example, the Bank financed an exploration program which resulted in a potentially significant discovery. The Bank was then able to direct resources from further exploration to the evaluation and further development of the resources discovered, mobilizing technical assistance, and providing the necessary financing which was not available from commercial sources.

Enhanced Recovery

While the problems of early development of petroleum discovery are important, the eventual efficient recovery of the reserves already proven also requires attention in developing countries. In most of them, oil is still largely produced through primary depletion of the reservoirs, which at best recovers only 5 to 25 percent of the oil in place. Methods to maintain reservoir pressure such as water/gas injection or assisted recovery (gas lift or pumping) are being used but not to the extent proven feasible in industrialized countries where pressure maintenance is now applied routinely from the outset of production. These projects, or more generally the rehabilitation of fields which have been producing for a long time, often imply large outlays of finance and manpower relative to the incremental production expected. It is generally true that investments based on established reserves have a lower technical risk and so are more attractive to the financial community. However, the first enhanced recovery project in a field will be risky since the technical processes involved are not proven. Here, the Bank's participation in designing and implementing a "replicable" technical package can not only increase production but also, by proving the usefulness of a new technique, open the way for future commercial financing of similar projects. To make such investments attractive to an IOC may require a specific agreement to ensure an adequate return on its capital. While some progress has been made in negotiating such agreements, particularly in Latin America, there are still considerable difficulties to be resolved.

- NOCs or host governments are usually slow to agree to adequate pricing provisions, mainly because it is very difficult to predict the incremental production from this type of operation, particularly if it has not been tried before in the country.

- Field rehabilitation and pressure maintenance projects have long gestation times and may never produce spectacular results; managers of national oil companies tend to prefer investments in exploration which, while admittedly more risky, have potentially higher returns.

- Such projects require sophisticated technology and expertise which NOC staff may not be familiar with and may, therefore, be reluctant to use.

- Finally, the accountability of the NOC in such projects is greater than in exploration, where anything approaching the world average success ratio is considered acceptable.

World Bank projects are addressing these issues in China, Peru, Romania, and Turkey. In several other development and exploration projects, studies have been initiated to assess the feasibility of enhanced recovery and provide governments and NOCs with the necessary information to consider developing such projects.

In summary, the World Bank can assist developing countries in accelerating the realization of their petroleum potential in a number of ways. The Bank can help countries in developing a realistic and appropriate petroleum sector strategy; it can help the countries to promote prospective acreage to the international oil companies so as to increase the level of private sector activity in the country; and it can help the government in financing its own program of petroleum exploration and development, wherever this is part of the appropriate petroleum development strategy for the country.

One of the most important conclusions of the Bank's recent experience in gas development is that the costs of gas development are lower and the potential domestic demand higher and more diverse than previously believed. Recent Bank studies also demonstrate that the cost of producing and transporting gas is well below the border price of imported petroleum fuels. In a large number of developing countries, better utilization of natural gas resources can greatly reduce dependence on oil imports or allow larger oil exports.

Natural gas reserves exist in about 50 developing countries, including 30 which import oil. Many gas deposits, mostly found in the process of exploring for oil, have not been fully evaluated because of the lack of immediate incentives to invest in their development. Proven reserves therefore underestimate potential supply, and in many countries they are being reevaluated upward, as governments become aware of the potential contribution to domestic energy supply. For many developing countries, even currently proven reserves of gas could supply about half of their long-term commercial energy needs.

Bank projections indicate a potential fourfold increase in natural gas production in developing countries, from 116 million toe in 1980 to about 424 million toe in 1995. This rapid growth rate is higher than those projected for other fuels, even though it is based on conservative estimates of domestic and export markets. Because of long lead times between discovery and use of gas and the slow rate of its development, production is also far below the potential that could be technically and economically supported by current proven reserves. In about 15 developing countries with sizable gas reserves, current production levels are, on average, only 16 percent of the level that current proven reserves could support.

Over 70 percent of the gas produced in developing countries is expected to be consumed domestically; only a few countries are potential exporters in this century. For developing countries as a group, the share of gas in commercial energy consumption is projected to grow from 7 percent in 1980 to about 12 percent in 1995, with the volume of consumption growing at 8.5 percent a year. In some developing countries, such as Bangladesh and Pakistan, gas is expected to supply half the additions to commercial energy consumption over the next decade. Over this period, developing countries as a group are likely to use 50 to 75 percent of their domestic gas consumption as fuel in electric power and industry, another 20 to 40 percent as feedstock in fertilizer and petrochemicals, and 5 to 10 percent in the residential and commercial sectors. In many countries with limited industrial infrastructure, particularly in Africa, the share of gas used for power is expected to be even higher than the average. However, achieving these substantial changes in the energy mix will require a strong commitment to formulate policies and to build and strengthen institutions in all gas-producing countries.

Gas for Domestic Use

In many countries, following gas discovery, the immediate question has been whether or not it is exportable. Recent studies by the Bank indicate that developing gas for domestic uses often provides much greater benefits to the economy, which can also be realized sooner, since such investments mature more quickly than those for export. This, together with the large front-end costs of liquefied natural gas (LNG) projects, the uncertainty of export prospects in the next decade, and the lack of direct linkage to economically productive sectors makes the domestic market the more important one for most countries.

Given the lumpy investments necessary for gas development, a long time horizon is needed for investment decisions and the estimation of production costs. A Bank study recently estimated the long-run marginal cost of producing and transporting natural gas in ten countries which have a variety of reserve and production characteristics, so that their results can be extrapolated to other countries.[5] For these countries,

5. The long-run marginal cost is estimated by dividing all discounted capital and operating costs by the discounted gas volumes. The discount rate used is 10 percent a year. These estimates exclude taxes and royalty payments; they also exclude a depletion premium reflecting the scarcity value of the resource. The ten countries are Bangladesh, Bolivia, Cameroon, Egypt, India, Morocco, Pakistan, Tanzania, Thailand and Tunisia.

the long-run marginal cost of nonassociated gas ranges from $10 to $55 per toe at the wellhead and from $12 to $75 per toe (equivalent to $1.65 to $10.25 per barrel of oil) at the distribution gate.[6] Most developing countries are at an early stage of gas development and the long-run marginal cost of gas is unlikely to rise. In all cases, the cost of gas at the distribution gate is far below the cost of imported petroleum products.

The marginal cost of associated gas, produced jointly with oil, is more difficult to estimate, and needs further study. The wellhead cost in most cases is negligible and the development and transmission costs are similar to those of nonassociated gas. In some countries, such as Brazil and Egypt, the cost of associated gas is low. But where fields are scattered, as in Nigeria, associated gas is more costly than nonassociated gas and its use may not be as economic as commonly believed.

Both associated and nonassociated gas include, in various proportions natural gas liquids, of which liquefied petroleum gas (LPG) and natural gasoline are a part. Since these products are easily marketable and are generally more valuable, the cost share allocated to lean gas on a heat equivalent basis, after allowing for the other joint products, is often very small.

The Bank has also reviewed the economics of natural gas use in the developing countries. Preliminary results from studies on the value or "netback" of gas in a variety of uses in the power, industrial, fertilizer and petrochemicals, and residential sectors indicate that gas is an economically attractive fuel in most uses.[7] The studies also show that the ranking of different uses is a highly country-specific and complex procedure. In planning gas utilization strategy, the netback values of gas in different uses, as well as the net present value and quantities of gas used for different projects, should all be considered. However, some general conclusions can be drawn, which are illustrated in Table 3.4.

The use of gas to generate electricity and as a boiler fuel can provide large economic benefits and in many countries this will constitute a major part of the total gas use. This is an important result for planning gas use because in most countries these markets already exist and can be tapped speedily and with relative certainty. The technology of conversion is well established and the required investments, both in infrastructure and equipment, are generally well justified by the economic savings from using domestic gas rather than liquid petroleum fuels. Once the distribution network for the main power and industrial users is set up, the cost of delivering gas to other users nearby also drops sharply, and additional markets for gas become economic.

The value of gas in the power sector and as an industrial boiler fuel depends on the costs of fuels it replaces, together with any capital cost savings. When used for small, peaking power units, gas can be very valuable, but the volume of gas thus

Table 3.4. *Illustrative Netback Values for Natural Gas in Developing Countries*
(1982 dollars)

Use	*Netback (dollars per toe)*
Power generation	
Peak (new diesel) thermal	340
Base (thermal system)	210/310
Base (hydro/coal system with coal replacement)	130/180
Fertilizer	
Developed site, domestic market	225/350
Developing site, limited infrastructure, export market	140/245
Developing site, limited infrastructure, domestic market	215/335
Residential/commercial distribution	
Existing city, without space heating	80/215
New city, with space heating	330/380
LNG	
Small scale, limited infrastructure	90/100
Large scale, with infrastructure	130

Note: The assumptions underlying these estimates are given in Annex 1.

Source: World Bank estimates.

6. These estimates are for large gas users. The costs of residential distribution would add about $86 to $450 per toe for burner tip equivalence. The range depends on population density, volume of use per household, and whether the city is existing or new. In many cases, gas competes favorably with kerosene and LPG, and it is cleaner to burn than most other fuels.

7. The "netback", or the average value of gas in a particular gas-using project, represents the gas price that would cause the project just to break even. It is defined as the present value of the net benefits of the project, excluding the cost of gas used, divided by the present value of gas consumed in the project. Both the net benefits and gas volumes are discounted to take account of their differing time streams.

used is generally small. For base-load power generation, the netback for gas may range from \$310 per toe when gas-fired combined-cycle plants can substitute for oil thermal plants, to \$210 per toe where gas is simply substituting for fuel oil, and to \$130 per toe in a system based on coal and hydropower. The comparison between hydro and natural gas power systems is complex and netbacks depend largely on specific hydropower costs, which can vary from less than one thousand to several thousand dollars per kW.

The value of gas in urea production also varies widely from country to country depending on whether the fertilizer is for domestic use or export, the location of the country in relation to the export or import center, and the state of existing infrastructure. Moreover, because of transportation costs, export-oriented fertilizer projects generally yield lower netbacks than those for the domestic market. In the former case, the netback falls as the distance to export markets increases. Netbacks for ammonia/urea are sensitive to end-product prices which have recently been fluctuating substantially. Since gas accounts for a much lower proportion of total costs in these cases than, for example, in power, varying assumptions on end-product prices or the cost of capital have a disproportionate effect on the gas netback value.

Where a gas transmission system exists or where one has to be built for industrial loads, residential or commercial gas distribution will often be worth considering. The most promising situations are medium- to high-density new urban developments, particularly where the housing is being planned and there are space-heating as well as water-heating and cooking needs. Residential gas use in developing countries is usually small. In many countries it will remain so, but in a number of them, such as Iran, Turkey, and Pakistan, this market could be significant.

The netbacks in Table 3.4 should not be the sole criteria for ranking and selecting projects. Other factors such as financing requirements (often billions of dollars for LNG), financial and economic risks, foreign exchange availability, the impact of projects on employment, and the technical and physical aspects of each alternative need to be taken into account. In addition, the quantities of gas and the rate at which markets grow vary substantially from use to use. If there is not enough gas to meet all competing demands, the low-volume uses with high netbacks may have to be traded off against higher volume alternatives yielding lower netbacks. In general, the first step in the selection would be to maximize the aggregate net present value of all the projects which could be supplied with the gas available.

Unconventional uses of gas represent a small share of total gas consumption, but they can be of particular importance to some countries and regions. In recent years, there has been significant technical progress in using gas as compressed natural gas (CNG), LPG, or methanol in transport, though confined so far to a few countries (notably Canada, Brazil, Italy, the Netherlands, and New Zealand). As the transport sector accounts for about one-half of total petroleum consumption in many developing countries and even more in some African countries, the economics of using gas as a transport fuel on a large scale deserve attention. Countries with large gas resources at a low cost, and where gas is transported to major cities, may find this worthwhile. The Bank has financed pilot projects in Bangladesh, Egypt, and Thailand investigating the potential use of CNG and LPG. Unconventional and marginal sources of gas, such as flared gas and coalbed gas, and gas pockets, have not been tapped in many countries. Again, technologies exist to make their use possible, but the economics have to be carefully evaluated.

Gas Pricing

Producer and consumer prices have an important bearing on gas development and use. Low producer prices and difficulties in achieving pricing contracts have discouraged companies from exploring for gas or developing it once it has been discovered in a number of countries, including Nigeria, Papua New Guinea, and Tunisia. Pricing disputes in Pakistan have reduced production far below demand and potential supply. Where consumer prices have been below long-run marginal costs of supply, gas utilities have made insufficient profits to support investments, particularly in transmission and distribution systems.

Prices should be linked to the economic value of the resource. Border prices are a good measure of this value when the gas is a tradeable commodity. Where this is not the case, the economic value of gas is determined by comparing demand and supply over time to ascertain the marginal use of the gas as development proceeds. Since the demand and supply balance changes over time, prices should be flexible but predictable. In Pakistan, for example, prices that may have been justified ten years ago do not allow for the higher marginal value of gas in today's market. In all cases, the long-run marginal cost will have to be considered along with other criteria such as the government's perceptions of the value (depletion allowance or rent) of gas as a depletable resource, impact of prices on the financial viability of gas producing and transporting entities, ease of administration, and the ability to pay of different consumer groups.

Exports

Natural gas exports from developing countries as LNG, or by pipeline, grew rapidly from 5.5 million toe in 1970 to about 40 million toe in 1982. Trade in LNG has grown more rapidly than the gas export market as a whole and developing countries, notably Algeria and Indonesia, account for 55 percent of current world LNG exports (see Table 3.5).

Table 3.5. *Major Gas Export Projects in Developing Countries, 1982*

	Gas volume (million cubic feet per day)			
Exporter	*Pipeline*	*LNG*	*Total*	*Destination*
Afghanistan	n.a.	—	n.a.	U.S.S.R.
Algeria		930	930	France
Algeria		565	565	U.S.A.
Algeria		250	250	Belgium
Algeria		450	450	Spain
Bolivia	200		200	Argentina
Indonesia		1,085	1,085	Japan
Iran	380		380	U.S.S.R.
Mexico	288		288	U.S.A.
Total[a]	868	3,270	4,148	

a. Excludes Afghanistan.
n.a. Not available.
Source: Institute of Gas Technology, Chicago, Illinois U.S.A. December 1982.

Over the next few years, trade in natural gas is expected to grow more slowly than in the 1970s. About 10 to 20 possible LNG projects in the developing countries are being reviewed at present.[8] There is a potential market for these exports principally in Japan and in Western Europe, but given the state of world demand, these projects will compete with each other and only a few may be realized in the coming decade.

LNG export projects require large proven reserves of at least 40 to 50 million toe (1.5 to 2 trillion cubic feet), large investments in equipment and infrastructure, and long gestation periods. In addition, they usually require extensive investments in ports, housing for employees, and community related services. Consequently, long-term agreements by buyers and sellers over the volume and price of gas are vital, and this makes LNG projects particularly sensitive to producers' and investors' perceptions of political and market risks. The economic, political, legal, and financial issues are unusually complex and require intensive study by highly skilled teams of staff and consultants at a high cost.

Regional gas trade is another prospective area of growth. Bolivian exports to Argentina, which the Bank has assisted, and Mexican exports to the United States, are examples which may be followed by the Bolivia-Brazil, Iran-Turkey, Bangladesh-India pipelines presently being studied.

Several developing countries not yet exporting gas, notably Bangladesh, Cameroon, and Nigeria, have large proven gas reserves which could support exports. In the next decade, gas trade will diversify, but it will still involve only about 15 countries that have substantial gas reserves and the advantages of the presence of international oil companies, closeness to markets, and perceived political stability.

Gas Development Strategy

Several developing countries, such as Argentina, Brazil, Egypt, India, Nigeria, and Thailand, with a combination of large reserves, low pro-

8. These include possible exports from countries such as Cameroon, Nigeria, and Trinidad and Tobago, which are not currently in the LNG trade.

duction costs, and a large number of high value uses, are on the threshold of major programs of gas development and have requested the assistance of the World Bank. In others, such as Bolivia, Cameroon, Chile, Ivory Coast, Morocco, Tunisia, Tanzania, Turkey, and Zaire, gas is beginning to be used and could well become a major energy source. A few countries, such as Algeria, Mexico, Pakistan, and Venezuela, already use gas to meet a significant share of their energy requirements. The experience of these countries illustrates the importance of formulating a gas development strategy at an early stage. They have well developed natural gas production, transmission, and distribution networks and competent gas agencies. However, most of them lack a strong institution to develop an overall natural gas strategy and integrate the activities of the various agencies. As a result, gas use projects have been selected in isolation, without coordinating exploration, production, and a broad study of different uses.

The main prerequisites for a gas development strategy are:

- A full evaluation of reserves, production potential, and costs.
- A detailed study of markets, including potential ones, and ranking of different uses under different supply scenarios.
- A clear contractual/economic framework to cover in particular the structure and level of producer and consumer prices, so as to ensure that gas-producing and gas-transporting companies recover their costs, and that gas is used efficiently by consumers.
- Finance for large and lumpy investments.
- An institution to integrate the activities of production, transmission, and distribution companies and consumers (for example, power, industry, and households).
- Personnel trained in the technical, economic, financial, and marketing aspects of gas, and efficient entities to produce, transport, and market gas.

Gas development planning is a dynamic process: it requires the country frequently to reevaluate its reserves and its policies toward depletion and utilization. As gas markets evolve, it may be necessary to shift gas to new, higher value uses that may take a longer time to develop. Prices should reflect changes in the supply and demand balance. Similarly, the relative importance of exploration changes over time as a better knowledge of both supply and future demand is gained. There is no unidirectional sequence consisting of (i) exploration, (ii) negotiation with companies on production and pricing terms, (iii) production, and (iv) use. In fact, without an assured market, pricing and related contractual agreements, and a commitment to provide the necessary infrastructure, a gas discovery is unlikely to be evaluated and even more unlikely to be developed. This vicious circle should be broken by developing supply and markets simultaneously.

On the supply side, exploration and development should proceed systematically to ensure that once a certain production volume is dedicated to a given market, other supply sources are developed to meet other known and potential uses. Private companies may be efficient individually, but an institution in the country needs to ensure that the sum of their activities achieves the country's objectives. Private oil companies and local and foreign investors require a clear understanding of government policies. A basic policy on the pricing of gas should be clear even before gas is discovered in order to motivate adequate exploration and appraisal activity by producers. This can be achieved by take or pay contracts, or by a flexible system of progressive taxes which relates prices to the economic value of gas so as to keep producers' returns within a reasonable range and protect the government's interests. Perceptions that not all commercial discoveries will be developed, as production potential may exceed market needs, often reduce companies' interest in exploration. The government should indicate the compensation it is willing to pay for successful exploration as well as the conditions under which it will permit exports.

The market for gas also needs to be evaluated regularly. A study of the potential for substituting gas for other fuels in use and plans for future industrial, power, and fertilizer plants, as well as residential sector demand, should normally be carried out. Not only should the existing long-term plans of industry be considered, but also the alternative industrial strategies that would become possible if larger gas reserves were

Box 3.2. *Assistance for Thailand's Gas Development*

Natural gas exploration, development, transmission, and domestic utilization makes up a large and growing share of the World Bank's assistance for petroleum development in developing countries. The Bank's involvement in Thailand is typical.

The discovery of gas in 1974 by Union Oil in the Gulf of Thailand, offered Thailand the chance to reduce radically its dependence on imported energy. Utilization of this gas depended on the Government being able to negotiate a mutually satisfactory agreement with Union Oil and on the timely development of the infrastructure and the market for natural gas. Because Thailand had no previous experience in gas, the Government approached the Bank for assistance. The Bank helped to formulate a comprehensive plan for the rapid utilization of the new resource, including the creation of a national capacity to manage the sector. It provided assistance in preliminary engineering, market evaluation, suggesting an adviser to the Government on negotiations with Union Oil, and helping to create the Natural Gas Organization of Thailand (NGOT) and its successor, the Petroleum Authority of Thailand (PTT). Advice was given on domestic gas pricing and on the roles to be played by public and private bodies in developing gas.

In establishing NGOT and PTT, particular attention was given to identifying staffing requirements, training, and developing capabilities for planning and programming, appraising investments, and monitoring projects. Needs for data and for research were identified and arrangements were made to secure them. A study of gas utilization examined the impact that Thailand's gas supplies will have on Thai industry and identified a number of gas-based industries, such as plastics and fertilizers, for optimal use of the gas.

The Bank helped with finance for three gas projects: for detailed engineering in 1978; for pipeline construction in 1980; and for gas treatment and liquefied petroleum gas separation in 1982. The second project helped build one of the longest submarine pipelines in the world at a total cost of $450 million. The Bank provided $107 million and helped mobilize $154 million in cofinancing from commercial banks and another $123 million from export credit agencies. Union Oil financed all of the field development. The pipeline was completed on time and within the original cost estimates; gas was delivered in September 1982 to South Bangkok and Bang Pakong, where it is now replacing fuel oil and diesel in power generation. Though there were some initial difficulties in producing the anticipated volume of gas, remedial action has been taken and the pipeline is expected to operate at full capacity within the next few years.

The pipeline was designed as a common carrier and routed through gas-prone areas in the Gulf, where its availability has helped to increase drilling activity and bring into production small offshore fields which would not otherwise have been commercial. In addition, private companies' interest in petroleum exploration and development has increased throughout the country: a field recently discovered by Shell is now producing and a discovery by Esso is being appraised.

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proven. A review of recent gas development projects financed by the Bank indicates that the development of proven reserves has often been delayed not for lack of adequate markets, but because there was no study to assess the size of the market and select the optimum use and consumer pricing strategy. Such information would also be helpful in promoting more rapid exploration, since the value of gas depends on an assessment of the market for its use.

Because producers, particularly if they are international oil companies, are unlikely to assume the risks of developing markets, the responsibility for planning, financing, and implementing projects for gas distribution and use rests with government agencies.[9] Consideration should be given to establishing a small gas development strategy unit to guide the efforts of the public and private agencies involved in gas development and to coordinate development plans for gas with the policies and investment plans of gas users.

Natural gas shares many of the characteristics of public utilities like electric power and water supply. These characteristics, together with the oil industries' demonstrated lack of interest in developing gas for domestic use, point to the important technical and financial role that can be played by the World Bank which has experience in power, water supply, and natural gas operations (see Box 3.2). The Bank can assist developing countries by:

- Financing gas transmission and distribution.
- Providing technical assistance to define better contractual arrangements and producer and consumer prices.

9. Possible exceptions are "enclave projects", such as fertilizers (Exxon in Pakistan) or export oriented projects (methanol, urea). Even in these cases, it is likely that projects will be in joint venture with the government.

- Financing market development studies and gas reserve evaluations.
- Promoting opportunities for private partners to invest in gas.
- Developing means of raising finance for gas secured against exports of oil products.

Coal

Coal is produced in about 35 developing countries, almost entirely for indigenous use. Coal remains up to 30 to 40 percent cheaper than oil as a fuel for electricity generation and for many industrial uses. However, this advantage is dwindling and in some developing countries it has disappeared, because of substantial inefficiencies in the management and coordination of programs involving coal and because of delays caused by government procedures and interventions.

Supply Outlook

In most developing countries in the years to come, coal will only be a viable alternative to oil if the governments and agencies involved can drastically improve the management of all aspects of the coal chain, including exploration, production, transport, and use. As Table 3.6 shows, substantial increases in coal production are projected for the period 1980–95: from about 500 million toe in 1980 to 886 million toe by 1995. Over 60 percent of the projected increase will take place in China and India and the aggregated projections are, therefore, highly sensitive to developments in these countries.

Table 3.6. *Coal Production in Developing Countries, 1980–95*

	Million toe		*Annual average growth rate, 1980–95*
	1980	*1995*	
China and India	359	594	3.4
Other large producers[a]	135	257	4.4
Small producers[b]	8	35	10.3
All developing countries	502	886	3.9

a. Twelve countries, each of which produced more than 2 million toe in 1980.

b. Twenty-seven countries, each with a 1980 production level of less than 2 million toe.

Source: World Bank estimates.

China is already the world's third largest coal producer (after the United States and the Soviet Union) and its 1980 production level was nearly five times that of any other developing country. Chinese coal production has been growing at 15 to 25 million tons annually over the past two decades and is projected to continue expanding at the somewhat higher rate of 20 to 30 million tons annually over the next decade (equivalent to about three percent a year). Although there is no reason to suggest that such large growth cannot be achieved, the projected increase is larger than any country has obtained in the past and its achievement will require a strong and sustained commitment. In India, the principal constraints that will need to be overcome in achieving the projected increase of 8 to 10 million tons annually (equivalent to about 5 percent growth a year) are the mobilization of the necessary resources, reductions in project delays, improved linkages with major customers, and removal of bottlenecks in transporting coal to the principal users.

Achieving increases as large as those projected will require the resolution of the issues which are discussed in the following pages. If these issues are not resolved, the effects could be significant—both reducing the quantities of coal available and raising their cost of production, thereby making coal a less competitive fuel. Small producers may be able to offset shortfalls by importing. But for larger producers, the effect on the pattern and cost of energy supply may be substantial. The Bank is helping a number of developing countries in addressing these issues as part of its growing program of operations in the coal subsector (see Box 3.3).

CONSTRAINTS. Considerable progress has been made recently in improving the geological and preinvestment data base on coal reserves for a large number of developing countries.[10] During the next decade, however, coal development will still be held back by a number of serious limitations: the heavy capital costs of coal develop-

10. Since 1978, the World Bank has carried out coal and lignite surveys in about 30 developing countries. Other multilateral and bilateral agencies have also been active in this area.

Box 3.3. *Helping Countries Develop Coal Policies and Projects*

The Bank has adopted a threefold approach to help expand coal output in developing countries: (i) attracting increased external and local capital for coal exploration, preinvestment work, and development; (ii) financing directly, coal exploration, preinvestment, and development projects; and (iii) helping individual countries to draw up and review plans for coal development.

During the period fiscal 1978–83, coal and lignite studies were undertaken in 27 countries; some of these were part of the Energy Assessment Missions (see Box 4.3). Based on the findings of the surveys, which will continue during fiscal 1984–85, the Bank is working with some of the countries to develop policies and projects to accelerate the production and use of coal whenever appropriate.

During fiscal 1978–82, six loans were made totaling $309 million; two for coal development projects and four for coal engineering and exploration projects. Two typical projects approved are:

- A $185–million loan for the Bukit Asam coal mining and transport project in Indonesia, estimated to cost $1.2 billion. The project involves the development of a coal mine to produce 3 million tons a year, upgrading of 405 kilometers of railway lines, and the provision of better port and shipping facilities. The project is to be implemented by the state-owned mining, shipping, and railway companies with specialized outside assistance. The Bank has mainly focused on the efficient implementation and coordination of the mining, transport, and power components and the introduction of coal pricing based on border prices to encourage more efficient resource allocation.
- A $17–million loan to a coal subsidiary of the Philippine National Oil Company to explore three promising coal-bearing regions and prepare feasibility studies. The project provides for training in the design and implementation of coal exploration and preinvestment programs, introduction of sound exploration and investment selection criteria in the coal sector, and compilation of sufficient geological preinvestment data to promote both local and foreign investment in the Philippine coal sector.

During the next five years, the Bank's coal program will focus on: (i) development projects in the large and medium-size coal producing countries (China, India, the Republic of Korea, Hungary, Yugoslavia, and Turkey), which will account for about 70 percent of developing countries' coal output growth during the coming decade; (ii) continuing support for coal exploration and development in smaller coal producing countries; and (iii) support for coal imports where these are an appropriate part of the country's energy development strategy.

ment, most of which need to be met domestically; the long lead times of coal investments; the shortage of adequately prepared, economically attractive projects; the difficulty in finding markets for export-oriented projects; and the limited engineering and managerial expertise in developing countries to implement a major coal expansion program.

COORDINATION. Lack of coordination in investments in coal, power, and transport is the major reason for the suboptimal use of investments in the coal sector. Traditionally, coal, power, and transport investments have been implemented by separate companies, depending on different ministries, often with widely different access to qualified staff and local and foreign funds. In addition, the implementation techniques, construction practices, and startup times of coal, power, rail, and port projects are very different, so that coordinating these projects can be very difficult. There are now many examples where programs cannot be completed as planned for lack of capital or human resources or where investments in one part of a program cannot be used efficiently because another essential part of the program has not been completed in time or is not operated efficiently. There is a risk that such problems will become more common in the 1980s. Governments and companies involved in coal production, transport, and use need to recognize that established procedures and traditions in the coal industry are often incompatible with the requirements and dynamics of complex integrated projects.

IMPLEMENTATION. Project implementation problems are another important limitation on the growth of coal supply. Speedy implementation of coal development projects is hindered by cumbersome bureaucratic procedures and restrictions, the lack of freedom of action, and low salaries in the public sector, which is responsible for coal production in many countries; shortages of local cost financing for investment programs; and a general lack of qualified manpower. Few countries have plans to develop a cadre of skilled manpower which is essential for future coal development and, because of the limited experience of multinational companies in this area, it is unlikely that this expertise can be quickly obtained "off the shelf". In addition, coal exploration programs are apt to suffer from:

- A dichotomy of objectives between geological survey institutes and coal producers and users—that is, between the need for systematic mapping and drilling countrywide and the need for faster coal production growth.
- The inefficiency of many geological survey institutes and mining companies in developing countries in managing exploration programs combined with reluctance to accept foreign technical assistance.
- Insufficient planning of exploration programs and targeting of optimal coal deposits, taking into account medium- and long-term coal use and transport patterns.

FINANCE. During the years 1975–80, 15 to 20 percent of total coal investments in developing countries were financed by external funds, 2 to 3 percent by private sources, and the bulk by government budget allocations or domestic subsidized loans. During the 1970s, coal prices in many countries were set to cover only operating costs, yielding virtually no funds for further investment. Delays in the allocation of public funds have repeatedly slowed down programs underway. Major changes are urgently needed in the coal-pricing policy of developing countries to limit cross subsidies and allow coal companies to generate a good part of the local funds required for expansion.

Formulating a Coal Strategy

In an urge to develop indigenous energy resources, physical targets for coal supply have sometimes been set without adequately evaluating specific investments. As a result, certain uneconomic projects, both private and public, have had to be subsidized (Argentina, Brazil, and Turkey provide only a few of the examples). In some countries, such as Turkey, coal development has become more costly because of long delays in implementing programs which were overly ambitious in their design and scope. Defining the management and manpower resources, the organizational and procedural framework required for coal development and adopting solutions for efficient implementation of coal programs will be essential if developing countries wish to realize the economic value and competitive advantage of coal. This requires the formulation of a well defined strategy which few developing countries, including the traditional coal producers, have so far carried out. Such a strategy would:

- Establish a realistic program for coal development, imports, and use in the light of the country's overall energy situation.
- Define the investment resources, the organizational framework, and the manpower needed for the program.
- Set out how these resources would be mobilized, noting the roles of the public and private sector.
- Provide for realistic coal pricing taking into account, on the one hand, coal production costs under reasonable standards of efficiency and, on the other hand, the requirements of the sector for investment finance.

Coal Imports

For many developing countries, imported coal is a potentially attractive option. In 1980, only four developing countries imported more than 1 million toe of coal, while eleven others imported 0.1 to 1 million toe—primarily of coking coal. In future, coal use in nearly all developing countries will be limited by difficulties in domestic supply. However, few developing countries are studying the options for importing coal, or have begun to make the necessary investments in infrastructure. Exceptions are a few Southeast Asian countries, Chile, and Cyprus. Many governments are stressing the indigenous production of energy, rather than replacing one import (oil) with another (coal), and government regulations often act as obstacles to such replacement. Consumers have also been noticeably reluctant to switch to imported coal, partly because they are unfamiliar with coal contracting and coal use and partly because they are uncertain about future international coal prices.

Although thermal coal imports in developing countries will increase only slowly, fifteen to twenty countries are likely to use imported coal by 1995. Government action to facilitate such imports will be required in almost all of these countries. First, many of the investments in the necessary infrastructure (port handling, storage, internal transportation, and so forth) will need to be publicly financed. And second, governments must act to make any necessary changes to the regulatory framework to permit coal imports and to encourage the large users (such as power plants and cement factories), who would generally initiate this shift to coal, to begin the necessary investments and to embark on long-term contracts with potential foreign suppliers. Since a shift to coal takes a long time to accomplish, many countries which are not presently planning to import coal should also explore if this is part of their least-cost energy development strategy.

Peat

Peat consumption in the developing countries is limited to household use of manually extracted deposits. The physical and thermal characteristics of peat *in situ* and, in particular, its high moisture content limit its widespread use. However, a few developing countries, including Bangladesh, Burundi, Indonesia, and Senegal, are currently investigating the potential exploitation and distribution of peat on a larger scale for household and industrial purposes. In Burundi, a Bank loan makes some funds available for a peat mining test. While, over the next decade, peat is not expected to make more than a small contribution to the overall supply of energy in developing countries, in some countries, it might help substantially to alleviate household fuel shortages or provide a source of thermal electricity.

Table 3.7. *Geothermal Development in Developing Countries*

Countries with projects or projects under construction		*Countries for priority geothermal evaluation*	
China	Mexico	Cape Verde	Korea, Republic of
El Salvador	Nicaragua	Costa Rica	Mauritius
Indonesia	Philippines	Djibouti	Rwanda
Kenya	Turkey	Ethiopia	St. Lucia
	Honduras	Guatemala	Tanzania
	Yemen Arab Republic		

Source: World Bank.

Geothermal Energy

Geothermal energy is the natural interior heat of the earth. As such, it occurs everywhere and the total resource is enormous, but only a very small proportion can be exploited with present technology. Geothermal energy is used mainly to generate electricity. Installed capacity for geothermal power generation in the developing countries in 1980 was just under 700 MW, about 38 percent of the world total. Nine developing countries have so far constructed such facilities which are generally economic only in areas of high temperature steam (see Table 3.7). The Philippines, with 559 MW installed capacity today and another 225 MW under construction, is second only to the United States in geothermal power production. The projected increase in geothermal power capacity, to perhaps some 4,000 MW for all developing countries by the early 1990s, is expected to take place primarily in the Philippines and other already-producing countries.

In countries with temperate climates, geothermal steam can be used directly for space heating. Geothermal energy has a much more widespread potential as a source of process heat in industry (such as food processing) or for crop drying. Unfortunately, the cost of developing geothermal resources by drilling is relatively high, so that industrial development must be on quite a large scale to justify the expense. It may be possible to use geothermal fields to provide electric power, process steam and heat, and distilled water to a cluster of processing industries. Such a concept might be particularly appropriate to small island sites where power demand alone is insufficient to justify geothermal development, but where there are natural resources to be processed.

The development of geothermal energy is held back mainly by lack of data and institutional drive. Only a fraction of the known potential thermal areas have been scientifically investigated and fewer developed. A number of countries can be identified for technical and economic evaluation on a priority basis. These countries, which are listed in Table 3.7, are characterized by good geological prospects and a sizable potential market for geothermal electricity.

Evaluating geothermal energy potential in a developing country requires a three-phase program. The first phase involves the collection of existing data on geothermal manifestations, the geochemical testing of surface samples, and a preliminary evaluation of the potential market. This reconnaissance phase may take one to two years in some countries and typically cost up to \$0.5 million. If the results are favorable, geophysical surveys of selected thermal areas are required. This second phase, lasting six to twelve months, would often cost between \$750,000 and \$1.5 million; many countries would need technical assistance. The final stage of such a program, drilling exploratory wells, may cost up to \$10 million and take up to three years. Appraisal wells must then be drilled and tested before a commitment can be made to construct a power plant.

Few countries are likely to undertake such a systematic program until the institutional difficulties facing geothermal development are resolved. The electric utilities, which are the main market for geothermal energy, have no background in mineral exploration and are disconcerted by the risk and uncertainty associated with this resource. Most oil companies see geothermal resources as a poor alternative to oil and gas exploration, often precisely because the only market for such a discovery would be the electric utility with which they have only limited interaction. Due to this lack of major alternative uses for steam in most locations and the relatively low initial risk of failing to find commercial resources, many companies feel a need to agree to a steam price with the electric utility even before commencing exploration; there are few international precedents for steam pricing. Moreover, the shortage of technicians and contractors experienced in geothermal development is particularly acute in the developing countries, though also of concern globally.

Such problems can only be resolved by concerted action. In the Philippines, for example, a group within the national oil company has been made specifically responsible for geothermal development. Electric utility managers should be made aware of the potential contribution that geothermal energy might make. Further study and contract initiatives are also needed to ease and speed up the geothermal contractual process and to take account of the uncertainties which may arise during field development. This is an area where the World Bank could be of assistance to developing countries, as in the case of natural gas. Even in the Philippines, where two international oil companies are active and others have expressed interest, several policy studies will be carried out under a World Bank loan (see Box 3.4). The Bank's involvement in geothermal exploration and development and geothermal power development has been limited to date (six projects), but it is now increasing, particularly at the upstream end. Other multilateral and bilateral agencies could also usefully orient their energy programs to provide more of the technical assistance and finance which most countries will need if they are to consider more seriously the use of geothermal energy.

Fuelwood

Recent studies confirm earlier evidence on the extent and severity of the fuelwood crisis. Nearly half of the world's population today lives in areas where fuelwood is acutely scarce or has to be obtained elsewhere; extrapolation of current trends in population growth, forest area, and planting programs suggest that up to 3 billion people will be living in such areas by the year 2000. The economic, environmental, and human consequences of this are very serious. Fuelwood gathering is one of the contributory causes of deforestation, which is already claiming about 10 million hectares a year of forests in the developing world, leading to soil erosion, reduced agricultural productivity, and siltation of reservoirs, river beds, and irrigation canals. The desertification of arid and semiarid regions increases as people remove vegetation in the search for fuelwood. The increased burning of animal and agricultural residues as substitutes for wood

Box 3.4. *Some "Unusual" Projects*

While the bulk of its lending program has been used to finance electric power, petroleum, coal, and forestry projects, the World Bank also finances less conventional projects when their technical, economic, and other characteristics make them priorities for borrowing countries. In Morocco, a $20-million loan is being used to study and test alternative means of exploiting enormous *oil shale* resources. The project includes construction of a test station using a locally developed retorting process, a comparative technical evaluation of available retorting processes using results from the test station and other data gathered worldwide, a feasibility study of commercial oil-from-shale operations based on several alternative processes, and a comparison of these results with those of a parallel study on direct combustion of the shale in a proposed thermal power plant.

In Brazil, a $250-million loan is contributing to the national *fuel alcohol* program. While most of the funds will support investments in sugarcane-based production capacity, part will be used to build cassava-based plants to demonstrate the feasibility of wood-based ethanol and other "new" technologies. The funds will also support basic and applied agricultural and industrial research related to biomass energy, and a system to monitor and evaluate the agricultural, transport, industrial, employment, and environmental effects of the fuel alcohol program.

Peat resources are the subject of a series of studies and tests supported by an IDA credit to Burundi. After a survey of the principal deposits and alternative extraction and processing techniques, large-scale on-site tests will be made and cost estimates prepared for a commercial operation.

Several countries (Kenya, the Philippines, and Yugoslavia) have obtained assistance in various phases of *geothermal* exploration and development. In Kenya, a 30 MW power plant was financed with the help of a $40-million loan and an additional 15 MW may be added under a second project now under preparation. In the Philippines, $36 million is being lent for the drilling of 25 exploration and appraisal wells, for associated technical assistance, and to finance geothermal policy studies.

The use of low-temperature geothermal heat for such purposes as greenhouse and residental heating is also the subject of a $700,000-loan component in Yugoslavia. Another component of the latter project provides $600,000 for the pilot installation of a *biogas* plant on a large pig farm. The renewable energy component of a project in Portugal provides a comprehensive package of assistance for resource and market studies, demonstration and pilot projects, and research and development activities in the areas of *solar, wind, and biomass* energy.

will have a further detrimental impact, by reducing the availability of valuable nutrients, and organic soil conditioners. The direct cost to rural and poorer urban households is also likely to be large. Many of these households have no real alternative to fuelwood other than greater use of animal dung or crop residues and the increasing scarcity of fuelwood is likely to cause major social and economic difficulty.

Although data on fuelwood production and consumption are inadequate, it is estimated that, even if the demand for wood can be reduced by 20 to 30 percent through conservation and replacement by other fuels, about 50 million hectares of trees would need to be planted in the developing countries between now and the end of the century to bring the projected demand and supply in the year 2000 into better balance. This would necessitate a fivefold increase over current planting levels worldwide; in Africa, a fifteenfold increase would be required. Most governments and international aid agencies are aware of the urgent need to increase fuelwood production and have recently stepped up their efforts in this area. Even so, the mounting of effective large-scale fuelwood planting programs is proving, by and large, to be a slow process.

Few countries have the infrastructure and institutional capability to support large-scale fuelwood planting. Strong local participation in planning and implementation is generally vital to the success of planting programs; however, fuelwood is usually most scarce where there is high population pressure on land and where people are consequently most reluctant to devote land and effort to purposes other than food production. Establishing nurseries and other facilities, and training foresters or special extension agents in rural afforestation, is a long process. The development of appropriate technical packages for a specific area also takes time, requiring extensive local trials and research to identify the proper species and provenances and the best combination of planting, fertilizing, or pest control techniques.

Quick action to deal with these problems is

Box 3.5. *Lending for Fuelwood: The World Bank's Experience*

Since 1978, the Bank has assisted in financing 31 free standing forestry projects, of which 16 are rural reforestation projects with major emphasis on fuelwood production. Nine are multipurpose reforestation projects producing industrial wood as well as fuelwood; three are designed to improve infrastructure and natural forest management, and are producing significant volumes of fuelwood as a byproduct of their logging operations; and three others involve the construction of sawmills in which sawmilling waste is either being used for power generation or for selling locally as fuelwood. During the same period, the Bank has also financed forestry components in 27 agricultural and rural development projects which have placed emphasis on providing fuelwood and construction poles for local use.

While the Bank's fuelwood projects have varied widely in scope and content, they typically include the following principal elements:

- Village-level studies to identify people's perceived needs and determine ways of reinforcing villagers' support for fuelwood programs.
- Surveys to estimate local needs for wood, assessing the volume of resources already available and quantifying the additional planting needed.
- Surveys to delineate marginal lands more suitable for forestry than for agricultural production.
- Demarcation and protection of village woodlots from fire and grazing.
- Construction of access roads or tracks to the forests and forest nurseries at the village level.
- Production of an assured supply of seeds or seedlings.
- Strengthening of government forestry services.
- Research into fast-growing tree species, technical problems, and potential economic benefits of agroforestry.
- Introduction of innovative technology such as more efficient woodburning stoves and charcoal kilns.

The social forestry project in the Indian state of West Bengal is a good example of alternative approaches adopted in rural forestry. Under this IDA-assisted project, free seedlings, some fertilizer, and a little bit of cash are offered as incentives to encourage the landless and marginal farmers to plant trees on farms that are essentially not suitable for agriculture. A thousand "motivators" at the village level, who include school teachers, are promoting farm forestry and providing useful feedback from users to the Government's Forest Department on the users' problems and preferences. The research component of the project will address such issues as alternative planting methods for farm forestry and collection and storage methods for seeds of indigenous tree and fodder species.

A group of projects in the Sahel countries is designed to develop suitable technical packages for improving the critical fuelwood situation in those countries. The second forestry project in Niger includes experiments to test whether highly productive irrigated plantations could be established close to Niamey. Most of the city's households depend for fuel on savannah woodland, which has now been cut down within a 50-kilometer radius of the city.

often impossible, since many national forestry services lack the expertise for the nontraditional tasks required in social forestry and forestry training programs are weak. In addition, some governments are still unaware of, or unmoved by, the fuelwood problem, or are unwilling to review the price and incentive structure essential to a sustainable fuelwood program. National programs, where they exist, are often poorly designed. Even when donors have provided support, it has not always been easy to mobilize domestic counterpart funding: long-term fuelwood programs are vulnerable to budgetary cuts during times of economic difficulty.

The Bank's own fuelwood lending experience confirms that a considerable amount of groundwork must normally be done over several years before large-scale planting programs can be implemented (see Box 3.5). Rapid implementation has been possible only in a few countries (India, the Philippines, and the Republic of Korea) where all or most of the following conditions have prevailed:

- Strong awareness of the need for tree planting exists at the farmer, village, and central government levels, frequently as the result of the increasing scarcity and rising prices of forest products.
- Land can be made available for planting trees—for example around homesteads, along farm boundaries, roadsides, and on marginal agricultural land.
- An adequate network of forest access roads

and tree nurseries exists, and an effective low-cost seedling distribution system has been devised.

- Satisfactory arrangements have been made for resolving conflicts between grazing and tree planting.
- An effective extension service has been created.
- There are well-developed cash markets for fuelwood to give a strong profit incentive.

The last point is worth elaborating. Urban and industrial users generally view wood as a commercial fuel, while many rural households perceive it as an essentially "free" good. Large state-operated plantations may help to supply the urban market, but the costs of producing and delivering fuelwood from such plantations may be higher than rural consumers are willing or able to pay. Fuelwood can be produced much more cheaply through onfarm and community planting programs using seedlings provided by nurseries run by the state, schools, or nongovernmental organizations, but the success of such programs depends heavily on whether people see tree planting as meeting a major need. This is more likely to be the case where trees can also be used for needs such as building poles and fodder, as well as fuel, and where tree planting is integrated with other agricultural activities, as part of comprehensive agroforestry programs.

Other Renewable Energy Resources

The sharp increase in conventional energy prices and the need to develop substitutes for fuelwood have aroused considerable interest in the other renewable energy resources of developing countries. This interest has been enhanced by a number of other factors. First, the developing countries are generally well endowed with solar and biomass resources and many of them have wind regimes and water resources which could also be tapped for energy. Second, although some technologies for harnessing these resources have long been in use—minihydro and windmills for example—recent technological advances have broadened their applicability and improved the efficiency with which they capture useful energy. Third, unlike fossil fuel deposits which yield energy in the relatively concentrated and portable forms suitable for large-scale industrial and urban use, many renewable energy technologies are best exploited on a small-scale, decentralized basis, and are thus well matched to the needs of dispersed rural populations. This relative advantage is heightened by the fact that conventional energy sources are frequently not available, or only available at high cost, in rural and remote areas of developing countries. Finally, much of the equipment needed for many renewable energy technologies is suitable for production in even the less industrially advanced, developing countries.

Recognizing these factors, many developing countries have embarked upon renewable energy development programs which are being supported by numerous donor agencies. However, with some exceptions—Brazil, China, India, and the Philippines, for example—efforts to realize the vast renewable energy potential of the developing world have not yet developed into large-scale national undertakings. There are two principal reasons for this. First, certain technologies are proving more difficult to develop, adapt, and apply and have remained more expensive than was foreseen. As mentioned earlier, designing socially acceptable and readily replicable improved cookstoves has proved to be a major task. While photovoltaic array costs have continued to decline, they have not fallen as far as was forecast, partly because the expected volume of production has not been reached. Biogas digestors have proved to be more complex and demanding to maintain and operate than many early investigators had assumed and conditions allowing the economic production of alcohol for vehicle fuel are less common than was anticipated.

Second, and perhaps more important, renewable energy development has been slowed down by weak institutions and policies. National programs are made more difficult to coordinate by the multiplicity of agencies—both local and international—involved. Most developing countries urgently need to begin formulating strategies for renewable energy development, which evaluate the potential of the various technologies, and their probable importance, in the light of the countries' specific energy needs and circumstances. In many cases, available information will give a good sense of the priority areas for renewable energy development and of what research and development and other preinvestment activities are needed in these areas. While in the long run there can be no substitute for comprehensive resource surveys and planning exercises, short-term studies of the potential of particularly promising resources and of the market prospects for specific renewable energy technologies can help to put ongoing programs on a sounder basis. It should, in particular, be possible to strengthen national programs by increasing the emphasis on:

- Assessing energy needs and resources to provide a firmer technical and economic basis for technology choices and investment decisions.
- Research and development programs to build national capabilities for assessing, adapting, and using new technologies.
- Commercialization, by providing greater support for manufacturers and vendors through market studies and the testing and certification of equipment; by developing closer linkages with programs in rural electrification, irrigation, and agricultural credit; and by promoting demonstration and pilot projects with private and public sponsors.

The site-specific nature of many renewable energy technologies and the different needs of different developing countries make it impossible to generalize about the emphasis that specific technologies should receive. However, most of them can be classified into two broad groups on the basis of their readiness for commercialization in the developing countries.

Technologies in the first group are, under many circumstances, technically and economically viable in developing countries today. Solar water heating using flat plate collectors for residential/commercial, and industrial uses is, perhaps, the most widely applicable technology in this group. In countries with good insolation, commercial and industrial solar water heating installations typically have payback periods of five years and one and half years when replacing oil- and electricity-based systems, respectively. Many developing countries (such as Brazil, Cyprus, Mauritius, Mexico, Morocco, and Papua New Guinea) have solar water heating programs underway, but to realize the potential of the industry will require governments' attention to a number of issues. Government-sponsored studies of market potential, as well as demonstration and pilot projects, research and development of new products, and public certification of these products to protect consumers, can all help materially to spread the use of new technologies such as this. Mechanisms to help consumers overcome the high costs of installing solar water heating include leasing arrangements and installation by the electric utility, which recovers the cost in monthly installments.

Other renewable energy technologies ready for commercialization include wind energy for small-scale water pumping and electricity generation, small hydropower systems, and alcohol production from biomass. While less broadly applicable than solar water heating, because it is much more site specific, wind energy is of greater development interest as a technology capable of supplying power in isolated areas. Even where wind speeds are quite low (three to four meters a second), Bank studies show that windmills can be the cheapest means of pumping water from moderate depths (for example, 20 meters). They require little sophisticated maintenance and simple water tanks can provide storage. These attractions have led to a modest revival of interest in wind pumping, mainly for village water supply and livestock watering in a number of developing countries including Kenya, Sri Lanka, and Thailand. Wind-based electricity generation requires somewhat higher wind speeds (generally over 4.5 meters a second) to be economically attractive and wind-based generators may be difficult to maintain, particularly in remote areas. One of the main constraints on the more rapid commercialization of windmills in developing countries is the lack of data on wind regimes, the collection of which should begin urgently. Increasing the availability of information on wind energy technologies and integrating wind systems into rural water supply and agricultural credit programs would also be an important contribution.

Small hydro is, like wind, a familiar and relatively simple technology whose costs are highly site specific. Costs for both equipment and civil works can vary widely but the average costs—about $1,900 per kW for the smaller systems (less than 1 MW) and $1,600 per kW for the larger ones (up to 10 MW) are within the usual economic limits for hydropower. Mini hydro has traditionally been seen as appropriate in those rural areas to which it is impracticable to extend the national grid. It can also be an attractive option for supplying electricity to the national grid, as in a recent Bank-assisted rural electrification project in Malaysia. The principal need in developing mini hydro is for cost-effective national programs that can deal with hundreds of small, widely dispersed projects in a field traditionally served by large centralized facilities. Methods for identifying and evaluating individual projects on a "wholesale" basis need to be worked out, as do means for building and operating large numbers of such projects. This can involve difficult institutional choices since the institutions with the greatest expertise (the utilities) may lack the necessary interest or adaptability, while those with the greatest interest (institutions for renewable energy or appropriate technology and local communities) may not have the necessary technical, managerial, or financial capability.

Alcohol production from biomass for use as a vehicle fuel is one of the best known renewable energy applications because of the large-scale program being carried out in Brazil. Several developing countries (for example Costa Rica, Malawi, the Philippines, and Zimbabwe) have begun small gasohol programs and others are examining the prospects for developing this resource. The experience of the past two years has confirmed that the economics of alcohol production are highly site specific and that, to be successful, alcohol projects require careful integration of activities in agriculture, industry, transport, and energy. The capital costs of ethanol plants outside Brazil have turned out to be higher than anticipated and the economics of alcohol production have been directly affected by the softening of world oil prices. In certain conditions—such as landlocked countries or remote locations where a surplus of molasses is available and the cost of gasoline is high—alcohol production is still an economically attractive option, but the number of developing countries where agricultural, industrial, and transport sector conditions converge to make alcohol production viable is more limited than was initially envisaged.

Many more technologies fall into a second group which show considerable economic promise, but where there are still some technical barriers to be overcome, further cost reduction is necessary, or greater operational experience is required, before widespread use in the developing countries can be expected. The more important technologies in this group are biogas installations in commercial livestock operations, large-scale electric power generation from wind and from wood, photovoltaic water pumping, concentrating solar collectors for industrial process heat, and biomass gasification for direct heat applications (such as greenhouse heating and crop drying) and for generating engine fuel.

The Bank program in renewable energy covers lending for fuelwood and alcohol projects to assist in the development of biomass resources; inclusion of renewable energy technologies in Bank projects to obtain operating experience to determine most economic systems and applications; and institution-building assistance to develop local capacity for utilizing renewable energy. The Bank has also undertaken a systematic review of the technical and economic status of several technologies; the results of the work on biomass gasification and on solar pumping have already been published. The Bank has contributed to the United Nations Conference on New and Renewable Energy by preparing with UNDP a global study in preinvestment requirements for renewable energy. It is also involved in the Action Programme recommended by this Conference.

Electric Power

The planning of electric power systems in the next fifteen years will be dominated by two considerations: the continued rapid growth of demand, and the fact that the power system can be an important instrument for changing the mix of a country's energy consumption. Demand for electricity grows relatively rapidly because of its versatility and efficiency in end-use; for some purposes (for example, computing), electricity is the only usable energy source. A clear manifestation of consumers' preference for electricity is the costs that industrial users in many developing countries are willing to incur to meet their own needs when supply from the power utility is inadequate or unreliable: about 20 to 50 cents per kWh, as compared to power tariffs in the range of 4 to 20 cents per kWh.

Historically, electricity use in the developing countries has grown at about 9 percent a year, although in some of the more rapidly industrializing countries (Brazil, Indonesia, Republic of Korea, and Thailand, for example), growth rates have been much higher. Over the past two years, the general slowing down of economic activity has reduced the growth of electricity demand in some developing countries, notably Brazil, but more commonly (in China, India, Indonesia, Pakistan, Sri Lanka, and Turkey, for example), the growth of electricity consumption is constrained by supply and there is a long waiting list for service. In such countries, the future rate of growth of electricity consumption will be determined as much by the schedule of commissioning new plants as by the growth in the underlying demand for electricity.

The growth of demand for electricity comes not only from new connections, but also from existing consumers. Though utilities can use changes in price and other techniques of load management to limit demand to a certain extent, in practice, it is impossible to limit consumers to a given amount of electricity. If capacity is inadequate, the quality of service deteriorates rapidly, with severe consequences for the equipment both supplying and using electricity. This means that once a power system is in operation, planning its expansion to meet less than the level of demand will inevitably lead to reductions in its efficiency.

Given these factors, the consumption of electricity in the developing countries is projected to grow at about 6.2 percent a year in 1980–85, rising to 7 percent a year in 1985–95 as economic activity picks up. Though lower than the past trend, this forecast, nonetheless, implies that electricity consumption will double during the 1980s and will continue to increase its share of total energy consumption. Even after this increase, the untapped market for electricity in the developing countries will be enormous: nearly 75 percent of the households in developing countries will still not have access to electricity; the industrial sector, the main user of electricity, will still account for less than 20 percent of GNP.

Power systems offer efficient means of using coal, lignite, and gas to distribute energy to a wide range of users. Some energy sources, such as hydropower, nuclear and, to a large extent, geothermal energy, can only be harnessed effectively in the generation of electric power. In countries which have appropriate energy sources, an important objective of the next fifteen years will be to modify the pattern of electricity generation, using the power system as an instrument to reduce dependence on imported oil. The large scope for this is evidenced by the major share of electricity in the energy sector: in 1980, electric power supplied 24 percent of the commercial energy consumption of developing countries and 30 percent of that of the oil importing developing countries.

Changing Generation Mix

For many countries, changing the energy sources from which electricity is generated is an essential part of adjusting to the higher price of oil. Plants using sources, such as hydro, coal, lignite, gas, geothermal, and nuclear energy, which may have been uneconomic at lower oil prices can now be developed profitably, even though they, typically, require larger investment outlays than oil-based plants. As shown in Table 3.8, and Figure 3.2, between 1980 and 1995, oil-based electricity generation is projected to decline by about 25 percent in absolute terms, and from 26 percent to 7 percent of total generation. This dramatic decline is caused mostly by greater reliance on coal, which overtakes hydro as the largest power source, and to a lesser extent, on gas and nuclear energy. The projections do not provide for any conversion of existing oil-fired units to coal, since recent studies show that this is generally more expensive than accelerating the construction of nonoil-fired units.

The scope for changing the generation mix depends on the size of the system and other country-specific conditions. A dozen developing countries with a sizable amount of low-cost energy to substitute for oil will be able to maintain the costs of incremental supply (generation, transmission, and distribution) between 2 cents and 4 cents per kWh. Examples are Algeria, Angola, Colombia, Gabon, Trinidad and Tobago, Uganda, Zaire, Zambia, and Zimbabwe. At the other extreme, several countries will continue to

Table 3.8. *Electricity Supply in Developing Countries, 1980–95*

	Terawatt hour			Growth rate (percentage per year)	
	1980	*1985*	*1995*	*1980–85*	*1985–95*
Primary electricity					
Hydropower	500	682	1,289	6.4	6.6
Nuclear	18	95	262	39.5	10.7
Geothermal	3	10	34	27.2	13.0
Subtotal	521	787	1,585	8.6	7.3
Conventional thermal electricity					
Oil	342	293	257	−3.1	−1.3
Gas	64	121	321	13.6	10.2
Coal	393	578	1,346	8.0	8.8
Subtotal	799	992	1,924	4.4	6.8
Total	1,320	1,779	3,509	6.2	7.0

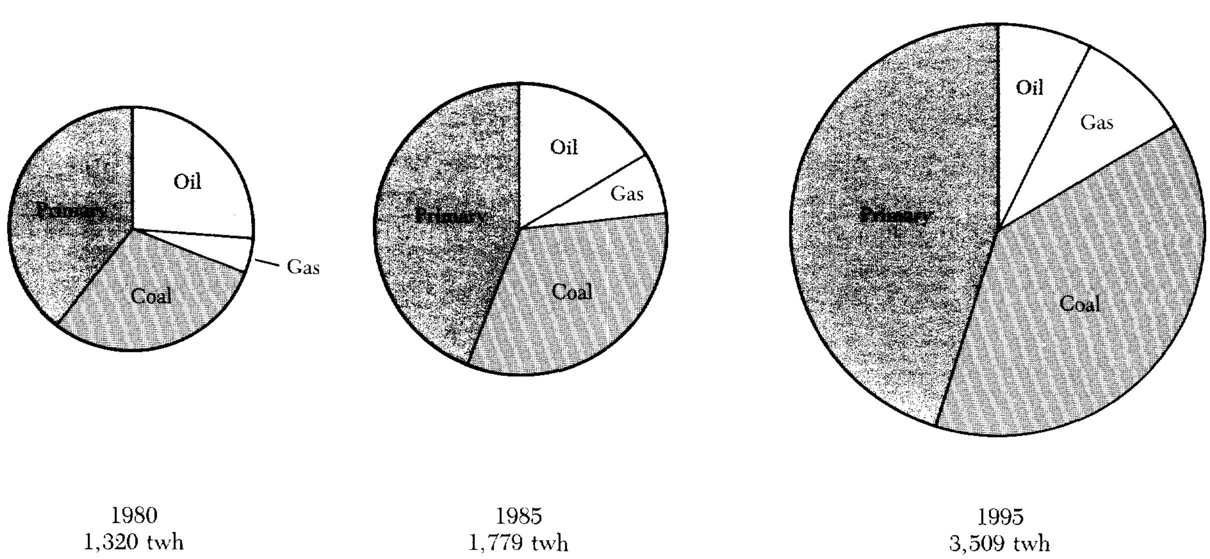
Source: World Bank estimates.

rely heavily on oil, or expensive hydropower, and will be unable to avoid costs of 12 cents to 24 cents per additional kWh; examples are Benin, Chad, Mali, Niger, Somalia, and People's Democratic Republic of Yemen. For this latter group, not only is the resource base too small, or very costly, to develop, but the use of imported coal is not economic because their power systems are small or because they are landlocked. In between these two extremes, most countries should manage to phase out a large share of their oil-based generation, keeping the installed capacity for peaking and cycling.

It may be possible to replace some oil-based generation with imported electricity. A key factor here is the development of national and regional interconnecting grids, which allow a pooling of resources and substantial economies of scale in generation and transmission.

For some countries without sufficient natural resources for the generation of power, nuclear power plants are an alternative. Two important considerations here are the significant economies of scale in their construction, and the fact that, for technical and economic reasons, they must operate close to their full available capacity. Less

Figure 3.2. *Electricity Generation Mix in Developing Countries, 1980–95*



than a dozen developing countries have power grids large enough to use the smallest economically viable reactors—about 600 MW—and for many of these countries, this increment represents several years of base load growth, limiting the scope for more than sporadic expansion programs. Even if technical progress and export credits make smaller reactors a more attractive alternative to coal-fired units in future, there will remain the major difficulties of ensuring good plant availability and that reactors and the fuel cycle are managed safely. The problem lies less in securing a highly trained elite than in establishing a broad basis of skilled manpower (200 people per unit) to operate and maintain facilities and strong regulatory institutions to monitor plant policies throughout their life cycle. Some countries already have some nuclear capacity and plan that, by 1995, nuclear energy will supply 15 to 50 percent of their electricity; they include Argentina, Brazil, India, Pakistan, Philippines, and the Republic of Korea. Countries such as Mexico, Romania, and Yugoslavia will soon start modest nuclear power programs. But for the reasons just outlined, by the turn of the century, nuclear power is expected to supply less than 10 percent of the electricity in developing countries as a group.

The economics of coal-based generation depend not only on plant size—the per kW cost for a 30 MW unit is twice that for a 300 MW unit—but also on the opportunity cost of coal. Large mine-mouth coal-based plants using coal at $40 per ton would produce electricity at about 4 cents per kWh, as against 7 cents per kWh from oil-based plants; the same units using imported coal at $80 a ton generate electricity at about 5.5 cents per kWh. Smaller coal units are competitive with oil-fired diesel units only under the best pithead conditions. About thirty developing countries are expected to use coal for electricity by 1995, with this source supplying over a third of total electricity requirements in about a dozen of those countries, including some new coal users. Lignite must be used at mine mouth and on a large scale to be economic, yet in spite of this and other technical difficulties, it is making an economical and important contribution in Romania, Thailand, Turkey, and Yugoslavia.

The role of gas-based generation depends greatly on country characteristics. In countries that produce gas, gas turbines are nearly always economic for peaking duty even though they do not replace much oil. The proportion of power generated from gas will largely depend upon the quantities of gas available and on whether the opportunity cost of the gas used makes it competitive with other sources for base load generation. For example, where gas is priced at $2.50 per million Btu ($100 per toe), electricity supply from gas-fired steam plant can cost less than 3 cents per kWh, and the cost of generation from more sophisticated combined cycle plants would be even lower. Gas could thus play a major role in generating electricity in many of the gas-rich countries such as Bangladesh, Indonesia, Mexico, and Nigeria.[11]

Hydroelectricity generation is projected to increase by more than 150 percent during 1980–95. Even after this increase, less than 15 percent of the harnessable hydro potential of the developing countries (about 7,600 billion kilowatt hours a year) will have been developed. The cost of hydroelectricity is quite site specific. Though $1,500 per kW is currently typical for many countries, unit costs for hydro projects in preparation range from $900 per kW in Colombia to over $5,000 per kW in Upper Volta. In general, real hydro costs are rising because the most attractive sites have been developed first. Where coal or oil is available at international prices, hydropower's economic limit is roughly $2,000 to $3,000 per kW; but proposed schemes must be studied individually. In some landlocked countries, such as Nepal or Upper Volta, schemes with significantly higher unit costs can be economically justified.

An imaginative effort needs to be made in harnessing energy resources now used on a limited basis for autogeneration, usually by industries beyond the national grid. The use of wood and crop wastes as fuel for power generation is well established in the wood and food processing in-

11. Combustion turbines located near wellheads could also be used to tap some of the enormous amount of associated gas which is currently flared in Nigeria and several other oil producers. Power generated from gas currently flared could provide hundreds of megawatts of low-cost base-load electricity to both national and, in West Africa, regional, networks. While energy collection by power transmission, instead of a gas gathering system, raises some still unresolved technical, economic, and political problems, this is an area worth exploring.

Box 3.6. *Electricity Generation Using Bagasse*

Bagasse, the fibrous cane residue from the process of sugar juice extraction, is traditionally burnt by sugar mills to generate process steam and power. Current annual sugar production worldwide is estimated to produce about 12 million tons of bagasse in excess of the sugar plants' normal requirements. This amount of fuel could substantially increase the electricity generated for public use. However, cane-processing efficiency varies widely from mill to mill, largely depending on the type and age of equipment used, with the result that some mills today have substantial amounts of excess bagasse while others require supplementary fuel for their operation.

A recent World Bank study identified several ways—all using presently available technology—to greatly increase the overall energy efficiency of existing mills, produce surplus bagasse, and generate electricity for sale to the grid. These include installing preevaporators to conserve steam, drying wet bagasse with flue gases to improve combustion efficiency, installing high-pressure boilers to increase steam generation efficiency, and pelletizing or compressing bagasse to enable it to be stored and used beyond the harvest season. The study identifies the conditions under which production of electricity by mills for the public is especially worth pursuing. In most of the scenarios studied, the economic returns were well over 10 percent at an electricity selling price of 6 cents per kWh.

The economics of cogeneration using bagasse have changed dramatically as the costs of conventional electricity generation have increased. To realize the potential of bagasse, as well as other agricultural residues such as groundnut shells, requires a coordinated effort on the part of utilities, the agricultural processing industry, and the governments concerned. Bagasse power cogeneration projects are presently being considered in Guyana, Mauritius, and other sugar producing developing countries.

dustries. For example, power from bagasse is used by the sugar industry to meet most of its energy requirements in some 76 developing countries and its use could be extended to augment public power supplies (see Box 3.6). However, there are institutional obstacles. Electric utilities are hesitant to increase their reliance on a new and untested supplier of energy. Meanwhile, the sugar industry is hesitant, or unable, to invest in upgrading its equipment to produce surplus electricity unless it is assured of a market at a fair price. Governments have a major role to play in helping to resolve these institutional questions by fostering mechanisms to bring together the various parties and resolve differences. Similar problems affect the use of other waste products for power generation.

Power System Strategy

As developing countries have had power systems for many years, the basic principles of system planning and operation are well known. However, the rise in oil prices and the consequent increase in the capital intensity of new generating plants have made the issues to be dealt with much more complex and reinforced the need for good planning and management because mistakes are now much more expensive than before. In this context, five points deserve special emphasis.

First, in searching for the least-cost plan for expanding generation, it is more important than before to evaluate a range of options, including the use of gas, imported coal, urban waste or agricultural residues, which might not have been economic at the oil prices of a decade ago. As alternatives to oil-fired generation generally require longer lead times, and may turn the power sector into the major single user of these primary sources, it is essential that plans have a long time horizon. At the same time, given the uncertain economic environment, it is necessary to keep some flexibility in planning; as power markets, resource data, and energy prices change and decisions on the scale and timing of key investments need to be reviewed and reevaluated periodically. As a result, several alternative projects must stand ready to be undertaken at any time.

Second, wherever hydropower is available, it is essential that major hydroresource surveys are undertaken to provide a data bank of alternative options for consideration as power needs grow. These surveys cost less than 1 percent of the ultimate investment in hydro projects and can lead to considerable savings by permitting the selection of optimal sites. Brazil has benefited enormously from the hydrosurveys conducted in the 1960s, which formed the basis for a major hydropower expansion program, minimizing the need for thermal generation.

Third, improvements which permit existing

Box 3.7. *The World Bank's Lending for Electric Power*

The Bank has been the largest international financier of electric power in developing countries since the first power loan to Chile was approved in 1948. It has been directly associated with about one-fifth of the total power investment in these countries in 1960–80 and with one-half of their investment in the development of hydropower. Over the past 30 years, power projects accounted for $16 billion—about 18 percent of the Bank's total lending—for some 400 projects in 85 countries.

During fiscal 1976–82, 136 electric power projects totalling $10.2 billion were approved (see table below). These totals exclude lending for electric power components of projects in other sectors. During 1978–80, the Bank lent $72 million for such components in 24 other projects in multipurpose irrigation, rural development, and tourism.

Although the reference period is short, the table illustrates the longer-term trend of Bank lending for electric power, with continued emphasis on hydroelectricity, a movement away from oil-fired thermal generation towards coal, some involvement in new sources (geothermal), and significant activities in transmission and distribution, including rural electrification. The aggregate lending for specific types of projects is derived from the sum of energy development programs in individual countries, but the distribution of lending roughly parallels the distribution of electric power investments for the developing countries.

The Bank's loans now, typically, amount to less than 5 percent of the investment programs they support, compared with about 30 percent in the 1960s. Equally, if not more important than its financial contribution, is the Bank's assistance in strengthening institutions in the power sector, by advising on priorities for system development, management structure, electricity tariffs, financial and technical operating practices, and by enhancing their ability to raise funds for expansion from domestic as well as public or private external sources other than the Bank.

The World Bank's Electric Power Lending, 1976–82
(millions of dollars)

		Generation						
Fiscal year	*Number of projects*	*Hydro*	*Oil/Gas*	*Coal*	*Geo-thermal*	*Transmission and distribution*	*Rural electricity*	*Total*
1976	20	208	71	—	19	592	59	949
1977	17	186	127	145	—	470	24	952
1978	19	348	97	305	—	256	140	1,146
1979	18	183	243	495	9	191	234	1,355
1980	24	783	52	840	40	589	88	2,392
1981	17	864	5	65	0	258	131	1,323
1982	21	122	200	700	—	713	396	2,131
Total	136	2,694	795	2,550	68	3,069	1,072	10,248
Percent		26	8	25	1	30	10	100

Note: Supplemental credits are not counted in the number of projects, but are included in the lending figures.
Source: World Bank.

facilities to be used more fully, and losses to be minimized, offer great scope for increasing power supply at lower cost. (Measures in this area were discussed in Chapter 2).

Fourth, as power utilities' financial requirements have risen sharply (for investment, working capital, and expenditures on maintenance and loss reduction), it is more important that they show better operating results and minimize reliance on budgetary grants. As pointed out in Chapter 5, domestic resource mobilization will be a critical factor in implementing power investments and power utilities need to take remedial measures in several areas, including raising power tariffs and tightening operating procedures. The Bank's lending program in power puts a strong emphasis on institutional development and on helping utilities to maintain financial viability (see Box 3.7).

Fifth, there are several cases where international interconnection of power systems, or binational projects could significantly reduce the costs of electricity supply—or improve its reliability—to individual countries. For instance, Nepal, Uganda, and Zaire have hydropower potential that can be efficiently used on a scale that

Box 3.8. *Financing of Refinery Conversions*

During the last three years, the World Bank has undertaken refinery sector reviews in 32 developing countries. As a result of these reviews, eight loans and credits have been made: to Argentina, Bangladesh, India, and Portugal for the installation of secondary conversion and energy efficiency facilities and to Pakistan, Peru, Zambia, and Zimbabwe for engineering and technical studies to determine the most economic sources of liquid fuels for the country and to help evaluate the economic and technical viability of proposed investments. The Bank has not participated in financing grassroot refineries.

The changing mix of petroleum products demanded in developing countries cannot be produced by the simple refineries that are typical in those countries; additional investments need to be made in their facilities to convert surplus fuel oil into middle distillates. Such secondary conversion investments normally do not add to the overall refinery distillation capacity, but remove a major structural problem faced by the industry worldwide. They are generally also highly profitable. For example, the secondary conversion projects supported by the World Bank are expected to earn economic rates of return ranging from 30 to 100 percent. The refinery rationalization project in India, which will install conversion capacity in five existing refineries at a total cost of $938 million, should lead to net foreign exchange savings of about $10 billion (1981 prices) during its 12 years of operating life.

exceeds their own needs and could serve neighboring markets economically. In West Africa, several hundred million dollars could be saved by developing Nigeria's abundant potential for thermal generation and linking it with its neighbors' hydro-based systems. Although problems stand in the way of these regional schemes, examples abound in the world (Itaipu, Central American Interconnection, Zambia, and Zimbabwe) to show that they can be solved even under a variety of institutional conditions.

Oil Refining

The slower growth of oil consumption has resulted in a global excess of primary distillation capacity in petroleum refineries. In the developing countries themselves, crude distillation capacity is estimated at about 1 billion tons a year, which should accommodate the projected growth in their oil consumption up to 1995.[12] Except under special circumstances, there is probably little need for investments in additional distillation capacity in developing countries. However, as discussed in this section, there is an acute need to rehabilitate and improve the energy efficiency of old refineries and to invest in new secondary processing facilities to convert surplus fuel oil into middle distillates (such as diesel oil, kerosene, and jet fuel).

Most of the refineries in developing countries are over 15 years old and were designed to minimize capital costs at the expense of higher energy consumption. The increased cost of energy over the past decade makes it worth considering several changes to increase energy efficiency. In addition, as refineries get older and because attention to maintenance, especially preventive maintenance, has generally been inadequate, substantial repairs and replacement of equipment are necessary (see Box 3.8). In evaluating the merits of each of such investments, it is important to consider the scope for rationalization on a nationwide or regional basis, as some existing refineries are too small and serve too limited a market to be economically and financially viable.

Because of the growing demand for diesel fuel (for transport vehicles and agricultural equipment), even though fuel oil is being replaced by the increasing use of natural gas and coal, developing countries' refineries will find it impossible to match the composition of their output of petroleum products with the changing composition of demand, which is projected in Table 3.9. The share of middle distillates is expected to continue increasing, reaching nearly half of petroleum demand in 1995, while that of fuel oil declines to about 21 percent in 1995.

Most of the refineries in developing countries are austere in design. Out of 245 refineries op-

12. Including new facilities that are expected to be onstream by 1985 and restarting facilities that are not operating, due to war or civil strife.

Table 3.9. *Structure of Petroleum Demand in Developing Countries, 1970–95*

	Percent			*Rates of growth (percentage per year)*	
	1970	*1980*	*1995*	*1970–80*	*1980–95*
Gasoline	15	14	18	5.5	4.26
Middle distillates	30	34	47	7.4	4.66
Fuel oil	38	35	21	5.2	−0.84
Others[a]	17	17	14	6.1	2.74
Total	100	100	100	6.1	2.75

a. Liquefied petroleum gas, bitumen, asphalts, lubricants, and solvents.
Source: World Bank estimates.

erating in developing countries, only about 60 have advanced conversion facilities such as hydro-crackers or fluid catalytic crackers. In developing countries, total secondary conversion capacity amounts to 13 percent of crude distillation capacity compared with 21 percent in industrialized countries. The inadequacy of secondary conversion facilities to process fuel oil into distillate products has compelled many developing countries to process more expensive lighter crude oil, often spiked with refined products, as well as to engage in sometimes unprofitable balancing trade in refined products. Taking into account facilities that exist, or are under construction, and assuming that secondary conversion facilities are fully used, it is estimated that by 1995 the production of middle distillates could not exceed 30 percent of refined products while fuel oil would amount to about 39 percent.

The relative scarcity of middle distillates and easy availability of fuel oil is expected to be a global phenomenon during the next decade and not one affecting only developing countries. A substantial share of the investment in conversion facilities needed to correct this product imbalance will have to be undertaken in developing countries. The economic returns from such investments depend on specific circumstances. However, it appears that if the current inadequacies and inefficiencies of refineries in developing countries were corrected, the economic cost of petroleum products for many developing countries could be reduced considerably.

The exploitation of domestic energy resources raises issues that vary from country to country and by type of fuel. However, most countries need to place much greater emphasis on developing a coherent and operational supply strategy in each of the energy subsectors which will identify clear development priorities and take into account the increasing interrelationships among these subsectors. This applies as much to the traditional energy sources—electric power and fuelwood, for example—as to those fuels whose exploitation and development is of more recent origin—nonconventional renewable technologies, or natural gas and coal for many countries.

A much larger share of resources—both human and financial—will need to be devoted to energy sector development in the future than in the past. Mobilizing and managing these resources effectively will, in turn, require considerably stronger institutions and policies for the energy sector in most developing countries. Donor agencies will have to make a commensurate effort in providing technical assistance for institutional development and policy analysis. The remainder of this report reviews the human and financial resource requirements that are associated with the energy supply and demand management programs discussed in this chapter, the potential options and prospects for mobilizing those resources, and the role of the World Bank in this cooperative effort.

4. Management of the Energy Sector

The sharp increase in the price of energy during the 1970s and the associated changes in the relative costs of alternative energy sources have imposed a colossal management burden on developing countries. All countries need to conserve energy and to replace expensive sources of energy with cheaper ones. Those that rely heavily on imported oil, especially, need to step up their efforts to identify and invest in their own energy resources. Designing and carrying out strategies for the energy transition requires better management both within enterprises supplying energy and at the national level, where there is a need to coordinate the activities of suppliers and to promote efficiency in energy consumption. The quality of management is the key to future investments; not only to identifying projects and implementing them successfully, but also to raising the finance for them. Chapter 5 explains that the developing countries will need to raise about $66 billion a year in domestic currencies to finance energy investments up to 1995. Energy enterprises must be able to generate large enough surpluses to finance at least a part of this investment. Equally large amounts of foreign capital will also be required. Though the international climate is a difficult and uncertain one, it is still true that, within subsectors, the best-managed enterprises will have the least difficulty in obtaining foreign funds.

Scope of the Problem

There are several reasons why management issues, at the national and enterprise level, tend to be complex in the energy sector, particularly during this period of transition. Not only are individual projects complicated to design and execute, but certain energy investments are complementary with each other while others are mutually exclusive, and decisions on energy are inevitably closely linked to almost every other aspect of development strategy. Moreover, these decisions have to be taken on the basis of imperfect information about the energy resource base and in an environment where future energy demand and relative prices are subject to considerable uncertainty because of factors over which energy policy makers themselves have little control.[1]

Several peculiar characteristics make the planning and management of energy investments especially complex.

- The resource base is unavoidably uncertain—either because its physical characteristics cannot be perfectly known before exploitation starts (in oil, coal, gas, geothermal energy, and hydropower), or for other reasons: for example, variations in the supply of bagasse for power generation, or of molasses or sugar for ethanol production, depend on the weather or the state of the world sugar market.
- The technology is often new, rapidly changing and risky. Offshore exploration, deep drilling, and enhanced oil recovery are dif-

1. For example, a slowdown in national economic growth can dramatically reduce the additional electricity needed in a given year and cause serious financial problems for an electric utility. In Brazil, a sharp slowdown in electricity demand growth, to 3 percent in 1981 from a historical average of over 10 percent, was due primarily to a cutback in national economic growth.

ficult technologies to handle, even for international oil companies, who often rely on specialist contractors. The more sophisticated techniques of power generation, such as combined cycle or nuclear, require extraordinary caution to avoid technical and economic errors, while underground coal mining presents continual environmental, health, accident, and organizational problems.

- The investments are lumpy: single investments often amount to several hundred million dollars and in some cases are as large as the nation's annual GNP. Mistakes are expensive. The scale of investment can give rise to formidable problems in assembling the finances from several different sources, both external and domestic.
- Projections of energy demand are highly sensitive to macroeconomic developments, which are difficult to predict.
- Energy investments require a long planning horizon, of 10 to 20 years. Over such a long period, there is a wide range of possible patterns of growth and structural change and hence of energy demand. This may make it worthwhile to keep some strategic options open as long as possible. The risks of so doing must be evaluated along with the conventional least-cost analysis of options.
- Since energy investments tend to be large, their gestation long, and their benefits difficult to estimate precisely, projects have to be carefully planned and quickly executed. The cost of delay or failure can be enormous. A hydroelectric installation, for example, that happens to have a lower generating potential than planned, or whose commission is delayed, could seriously affect the viability of a number of other projects.
- Some investments in fuels, or in equipment to use them, must be made before the markets for them are assured, so that efforts are needed to promote their products: examples are improved woodstoves, liquefied petroleum gas for household or vehicular use; and charcoal, solar, or other renewable energy sources.
- Because energy investments are both very risky and offer potentially high rates of return, it is often necessary and feasible to involve foreign equity partners. This requires negotiation of suitable arrangements to share the surplus.
- The limited extent of domestic private sector activity in energy production and supply in most developing countries places an extra management burden on the public sector in this area.
- Environmental considerations are also important. The development of a large hydro project could entail the inundation of settled rural areas; coal-burning power stations or industries can seriously pollute the air unless appropriate equipment and controls are installed. These environmental effects have to be explicitly considered in the course of evaluating alternative energy investments.

Decisions on energy investments can rarely be made in isolation. The timing of hydropower investment, for example, depends on the projected growth of electricity demand, which often depends critically on a few, large industrial users; the planning of a gas pipeline may be linked to the location and timing of a fertilizer plant; the design of a refinery may depend on the projected evolution of transport demand and the type of vehicles in use. Investments to supply alternative fuels to households may have to be judged on the basis of detailed market surveys and predictions of consumer behavior. Such decisions require the installation of extensive infrastructure (such as roads and pipelines) and equipment (refineries, processing plants, and compression stations) that is highly capital intensive. Choices among alternatives can be complex. If there is only one economic option for energy supply, its adoption is not open to question if its actual cost turns out to be significantly higher than estimated. But if there are several options whose estimated costs are close (for example thermal or hydropower in Kenya; coal-fired or geothermal power in Indonesia), it becomes much more important to ensure that the initial cost estimates are accurate. At the margin, some of the options (some hydropower projects, coal mines, or enhanced oil recovery) may be more expensive to the economy than the import of oil. The evaluation of these projects must carefully consider the tradeoffs between cost of supply and strategic considerations such as achieving national self-sufficiency in energy.

Energy is an input or an output in almost all productive activity and, consequently, the linkages between energy and the rest of the economy are strong and intimate. Not only do energy investments compete with those in other sectors for scarce investible resources, decisions on them cannot be taken without careful consideration of their interrelationships with policies and trends in the rest of the economy. These relationships have many dimensions. The impact of oil imports and exports on balance-of-payments prospects is well recognized and, for most countries, trade in oil directly affects development prospects. In oil exporting countries, production arrangements and depletion policy can be rationally established only in the context of a long-term view of development priorities and *vice versa*. In all countries, industrial strategy is closely linked to energy demand and energy costs have a strong bearing on the profitability of different industrial options. The long-term impact of energy prices on industrial structure and efficiency is significant. The same applies to policies affecting the pattern of urbanization, transport, infrastructure, and the relative emphasis on different modes of transport. Measures to increase the supply of fuelwood will involve changes in the management of forests and pattern of reforestation which, in turn, may conflict with existing agricultural practices. These linkages pose a special challenge for the managers in this sector: though the developments outside the energy sector are largely out of their control, the latter have a great bearing on the success of their efforts.

Linkages are important not only in investment programming, but also in decisions affecting the structure of prices. Energy prices not only influence the choice among fuels and the financial viability of energy investments and energy producers, they also have a direct impact on the distribution of real income, since energy is a significant item in household expenditures. Therefore, energy prices can have a significant indirect impact through their influence on the profitability of industries and services ranging from steel mills to biomass collection.

Weaknesses in Management

Few countries, industrialized or developing, have coped altogether successfully with the challenges posed by energy developments over the last decade. It is hardly surprising, therefore, that developing countries have management problems both at the national and enterprise levels. Weaknesses in management can have an enormous impact. For example, in coal, poor maintenance and failure to plan for the availability of spare parts can keep between one-fourth and two-thirds of the mine-trucks out of action, while operators who lack proper training may lift only half the normal volume of coal per shovel. In power, huge technical transmission and distribution losses may not even be recognized, if operational losses are not properly analyzed and revenues are not collected efficiently (see Boxes 4.1 and 4.2).

The most common weaknesses in energy enterprises can be found in all types of public enterprises in developing countries. These weaknesses include insufficient experience and training of the key staff, inadequate facilities for training and ill-designed curricula, poor management practices, and lack of familiarity with technologies and operating practices in more advanced systems. They are compounded by poor infrastructure, a lack of specialized consultants, and the generally low level of education and skills among the work force. They are also exacerbated by the tendency of enterprises to use their own scarce managerial and technical staff for tasks that could be subcontracted to private industry on a long-term basis. Where too few technical staff are available, managers concentrate on crises to the neglect of training new staff and of preventive maintenance, leading to a vicious circle of new crises.

Because of their large scale and strategic importance, energy supply activities are generally managed by government or quasipublic enterprises. It is entirely appropriate that long-term objectives and strategic issues be determined by a high political authority, but within clear national guidelines, the operating enterprises must be free to make final decisions on operations. In practice, supervision by government ministries

Box 4.1. *Improving Efficiency in Operating Power Systems*

In most developing countries today, the most cost-effective way of increasing the supply of electricity is to improve the efficiency of existing facilities. This can be done by making more generating capacity available, improving the efficiency of thermal plants, and by reducing losses incurred in distribution and transmission (see also Box 2.2). The World Bank routinely investigates these options as part of its appraisal of power projects.

- The introduction of computer-designed turbine runners can increase both the capacity of hydroelectric plants and their generating efficiency. The Bank is preparing a project in Uganda where a change in runners will result in a 40-percent increase in output (at higher efficiency).
- If thermal plants are not operated at optimal conditions of temperature and pressure, significant amounts of fuel are wasted. A one-percent increase in the operating efficiency of a 300 MW coal-fired unit, for example, could save $1 million annually. As part of a Bank technical assistance program, a consultant conducted brief audits of thermal power stations in Guatemala, Nicaragua, and Uruguay and identified operating improvements which typically would reduce annual cost by $4 million per station with minimal investment. The findings are now being incorporated in Bank projects.
- The Bank urges its borrowers to carry out preventive maintenance. Reductions in the availability of existing units need to be offset by additions to capacity if a utility is to maintain the same level of reliability. For a large utility that is adding one 300 MW thermal unit every year, a one-percent improvement in the availability of units would save $6 million a year.
- Plant betterment studies promoted by the Bank have shown that simple corrective measures, such as cleaning blocked condensers, or repairing leaking valves, can have payback periods as short as a few days.
- It is important that appropriate spare parts be on hand. As a part of project appraisal, the Bank reviews the utility stores position and sometimes finances spare parts as a project component (as done in Tanzania and Zaire).
- Financial losses from electricity that is stolen or improperly metered, so that consumers are not charged enough for it, seriously affect the profitability of many power utilities and should be minimized. On one Bank project in Afghanistan, a program covering both rehabilitation of customer meters and improved collection procedures virtually eliminated unpaid consumption over a five-year period.
- A gas turbine operation and maintenance training program was included at the Bank's suggestion in a UNDP-funded technical assistance project executed by the Bank in Egypt; it has resulted in an estimated 20 percent increase in generating plant availability.
- A vital element in achieving such improvements is expanded and more effective training of utility staff. Most Bank projects include a training component. For example, a recent project in Bangladesh included a simulator for use in training thermal plant operators.

can sometimes extend to interference in routine decisions by civil servants who lack operating knowledge and may not share responsibility for failures. Under these pressures, even when enterprises are formally autonomous, key decisions may be delayed, unrealistic objectives imposed, or enterprises' needs neglected. When these factors are combined with regulated wage and salary structures dictated by government, and time-consuming procedures for procuring and allocating funds, the frequent result is a lowering of morale and a loss of experienced managers and skilled staff. These problems are generally most acute in the power and coal subsectors.

The task of managing energy enterprises is made more difficult by the diffusion of responsibilities at the governmental level. As many as a dozen ministries sometimes make decisions and issue independent regulations bearing directly or indirectly on the energy sector. Various public or private organizations, such as industrial or agricultural development banks, may appraise investments involving energy without referring to the Planning Ministry or any other authority. There is, thus, an inherent risk of conflict in a crucial area of national economic development.

Priorities for Action

The preceding analysis has identified a variety of areas for urgent action to strengthen the developing countries' ability to manage the energy sector. While the priorities for action in each country will need to be determined within the specific context, two areas which require widespread attention are the need to improve the quality and volume of preinvestment work, and

Box 4.2. *Improving Efficiency in Oil and Gas Production*

The efficiency of oil and gas production can be improved by inducing the more rapid development of reserves and increasing the rate of recovery from reserves. Both of these effects can be achieved through three types of actions: improving the environment for petroleum operations so that they become more profitable; improving the management of these operations; and introducing technologies which increase the proportion of reserves that can be recovered.

All three types of action generally require greater access to international expertise, finance, and technology; they also feature prominently in the World Bank's program for petroleum development. In its sector work and policy discussions with governments, the Bank discusses and advises on national systems of petroleum pricing, taxation of petroleum operations, government procurement systems, and salary structures that affect the efficiency of public-owned oil companies. In Ecuador, for example, an independent audit of petroleum reserves, carried out at the Bank's urging, has strengthened the government's reserve to offer better legal and contractual arrangements to private oil companies. The preliminary results of the study also motivated the government to agree with Texaco on the rapid implementation of a water injection scheme which will allow the country to continue as a net exporter of oil in the medium term. Other companies are now beginning to explore and produce in the country.

The Bank also advises national oil companies on managerial structure and practices, assists with planning and with oil companies' pricing policies, and helps to select expert consultants where needed. In Peru, for example, Petroperu, the national oil company, is being reorganized on the basis of recommendations by consultants and the Bank. To streamline production operations, improvements are being made in its accounting, financial administration, and management information practices and procedures, while studies are in progress on pricing of petroleum products and investment priorities. The Bank also recommended that the company install a corrosion control and monitoring system (for wells, pipelines, and storage tanks), including the establishment of, and training of staff for, a special unit within the company. By attacking corrosion problems early on, Petroperu will be able to avoid costly shutdowns like that which occurred in 1981 on the Trans-Andean pipeline.

Introduction of new but proven technologies in exploration drilling and oil field development is common in Bank petroleum projects (see Box 6.1). One loan is financing enhanced oil recovery through selective injection of carbon dioxide in Turkey's largest known oil field, Bati Raman. This new technology, used previously only in Romania, the Soviet Union, the United States, and Venezuela, has permitted oil production in this field to increase threefold. A similar approach may be used in Bank projects in China and India. In a gas field in Turkey, production has been increased almost tenfold by the use of well stimulation techniques, particularly hydraulic fracturing. Further development of this field has now become highly economic and such techniques have been accepted by Turkish authorities as the standard way to increase the production potential of gas discoveries in the Thrace basin. In Ivory Coast, Petroci and its foreign partners followed the Bank's recommendation to carry out a three-dimensional seismic survey. This will save the drilling of dry holes in a field with very complex geology, but it will also allow the definition of new reserves and, possibly, a subsequent increase in production.

to strengthen the strategy formulation, overall management, and manpower capability, at both the enterprise and national levels.

The importance in the energy sector of good preinvestment work needs to be emphasized. To plan power generation, for example, it is necessary to identify the least-cost generation plan, which in turn requires a systematic survey of the hydropower potential in the country. Such surveys require hydrological records covering many years to determine river flow patterns under various conditions. Unfortunately, such records are still lacking in most developing countries. In a recent study by the World Bank of preinvestment requirements in hydropower generation worldwide, it was concluded that about $2 billion would be required for surveys and studies over the next decade. Related roughly to the 180 GW of hydro capacity to be added during 1985–95, this amount is only about 1 percent of the final investment cost and is well justified in terms of potential cost savings alone. Apart from the financing, what is lacking is the recognition that such surveys are important and the preparatory work and administrative arrangements to implement them. On a smaller scale, but equally important, is preinvestment work in other energy subsectors: geological and geophysical studies to guide petroleum exploration; preliminary studies of the market potential for natural gas so that

Box 4.3. *The Energy Assessment Program*

The World Bank and the United Nations Development Programme in November 1980 jointly launched a 60–country Energy Sector Assessment Program designed to provide a rapid diagnosis of the major energy problems faced by the developing countries and to evaluate the options for solving these problems. These assessments analyze the policies that would encourage greater production from indigenous energy sources and greater efficiency in the use of energy; they judge the investment priorities in the energy sector; and they provide a framework for multilateral and bilateral technical assistance in the sector.

Assessments completed since November 1980	*Assessments in progress*	
Bangladesh	Benin	Peru
Burundi	Bolivia	Portugal
Haiti	Colombia	Senegal
Indonesia	Costa Rica	Solomon Islands
Kenya	Ethiopia	Sudan
Malawi	Fiji	Togo
Mauritius	Morocco	Uganda
Papua New Guinea	Nepal	Yemen Arab Republic
Rwanda	Niger	
Sri Lanka	Nigeria	
Turkey		
Zambia		
Zimbabwe		

The costs of these assessments have ranged from \$50,000 to \$250,000 per country and the reports are being submitted to governments about eight months after the field missions. Each mission, which normally includes four to eight participants and stays in the country for up to one month, responds to a specific request from the government for advice on the energy sector and follows agreement with the government on the priority issues to be tackled.

The response to the Assessment Program has been strong and requests have been received from more governments than the 60 originally envisaged. The recommendations made in the assessments cover a wide range of actions in the areas of pricing (in Bangladesh and Indonesia), energy efficiency (Malawi, Sri Lanka, and Turkey), interfuel substitution (Indonesia, Mauritius, and Zambia), institutional reform (Sri Lanka and Turkey) and, most importantly, priorities for investment and preinvestment work. Governments are making extensive use of the advice and many have requested further assistance, either for the more detailed analysis of specific policy or preinvestment options or, more generally to improve the management and institutional framework for the sector. For this reason the UNDP and the Bank have recently launched an Energy Sector Management Program encompassing these activities (see Box 4.4).

discoveries can be speedily exploited; and the collection of site-specific data on wind speeds and insolation.

The organization of preinvestment work is only one aspect of a broader need to strengthen institutions in the energy sector. It is necessary to establish a working environment (including adequate salary levels) that will maintain the continuity of management and help to retain qualified staff and to upgrade their skills. The latter will involve formal training and refresher courses as well as closer contact with experienced staff in international industry, consulting firms, and lending agencies involved in project preparation and appraisal.

It is also necessary to ensure that major proposals concerning investments and pricing are analyzed with a broad perspective of the sector and the nation, rather than in an isolated, uncoordinated manner. This is particularly important given the uncertainties affecting the future evolution of energy demand and supply. To achieve these changes will require both staff (engineers, financial analysts, and economists) devoted to long-run planning at the enterprise level and a small, qualified group of analysts at the national level to advise the key decision makers on overall sector policy issues and on ways to strengthen the institutions operating in the energy sector.

The planning staff at the national level would be responsible for coordinating enterprise plans (for example, by ensuring that enterprises make the same assumptions about the growth of energy demand and interfuel substitution trends, or that the projected demand for different fuels for power generation is consistent with the projected availability of these fuels), and for formulating a strategy to achieve specified goals. They would also be responsible for evaluating the effects of ex-

Box 4.4. *The Energy Sector Management Program*

The United Nations Development Programme and the Bank have recently launched an Energy Sector Management Program designed to provide a rapid and flexible response to governments who request assistance in implementing the policy, planning, and institutional recommendations of the Energy Assessment Reports (see Box 4.3) or in carrying out prefeasibility studies for energy investments identified in these reports.

The Energy Sector Management Program can finance:

- Assistance to improve a government's ability to manage its energy sector, for example, by defining staffing and work programs, evaluating management information needs, identifying sources of public and private finance, and developing a medium-term investment plan.
- Prefeasibility work on priority investment plans, especially those which will improve the efficiency of energy use and those which will provide enough affordable energy to rural areas.
- Providing specific short-term assistance in institutional and manpower development.

The program aims to supplement, advance, and strengthen the impact of bilateral or multilateral resources already available for technical assistance in the energy sector. Though it is already underway, further resources are being sought from major donor agencies in order to realize its full potential to respond to the urgent requests of developing countries.

ogenous changes (for example, in economic growth or international energy prices) on the demand and supply prospects for individual fuels, and for ensuring that subsector investment programs and pricing policies were altered quickly to take account of these changes. A central energy secretariat may also be concerned with efficiency in energy use. It may oversee programs to reduce energy consumption, promote research studies and experimental projects for improving efficiency in the use of energy, and disseminate information on how to save energy. It would ensure that adequate financial and managerial resources were being devoted in each of the subsector operating agencies to improving the efficiency of existing plant and operations. This is important even if the energy source is imported (for example, petroleum products). Significant reductions in the oil import bill can be achieved by switching to alternative sources or methods of supply.

The location of the national energy policy staff will vary by country, depending on specific needs and institutional arrangements. The important requirement in all countries, however, is that energy planning be an explicit element of national planning and public investment decisions and that the national staff should have adequate authority to review all proposals with significant energy implications.

Role of External Assistance

The main effort to improve energy management has to come from the countries themselves. In some vital areas, for example, in the reform of the relationship between government ministries and public enterprises, external agencies, such as the World Bank, can highlight the problem and advise on how it is being addressed in other countries. In other areas, there is greater scope for external assistance in improving enterprise management structures, accounting systems, and procedures for billing and collection, planning, operations, and maintenance, even though the social and political frameworks within which solutions must be sought are fully known only in the countries concerned. International financial agencies can also help by preparing terms of reference for selecting and supervising the performance of consultants for pricing studies, in establishing priorities for preinvestment work, identifying the manpower and financial requirements, and mobilizing the funding. Through their joint Energy Assessment and Sector Management Programs, the UNDP and the World Bank are assessing the major energy problems of developing countries and helping to evaluate options for solving these problems and improving energy sector management (see Boxes 4.3 and 4.4).

Training is an area where specific external assistance may be useful in several ways:

- Programs within countries to train specialists in energy planning, economics, technologies, finance, and environmental aspects; on-the-job management and technical training in energy companies.
- Workshops and seminars at which technical experts from developing countries exchange ideas and experience.
- Overseas training courses in various specialties.
- Secondment of key individuals to foreign energy sector institutions and financing agencies.
- Reorientation of training and educational institutions and programs in the country concerned.

Training should be carefully focused to benefit the country in areas where it is most needed and can be of lasting use. For instance, unless the petroleum prospects of a country are well established, there is no point in training people for specialized tasks in petroleum production or gas pricing rather than in the basic skills of geophysics or surveying which can be employed in a wider range of activities, including mining and construction. Similarly, training in building sophisticated models of the energy sector is of little value in countries where basic data and analysis of energy issues are still rudimentary. At the same time, the benefits that accrue from a well designed and well administered training program must be emphasized. The high rates of return for such training make its (generally) higher cost well worth incurring and it is frequently a prerequisite for realizing the full benefits of far greater investments in plant and equipment.

5. Financing Energy Investments

The magnitude of the energy investments required in developing countries poses a formidable financing problem. Oil importing countries, in particular, not only have to find the resources for energy investments that are more costly than before, they also have to finance imports of oil until these investments, and those to increase the efficiency of energy use, begin to pay off. To meet the energy demands of developing countries would require investments of about \$130 billion a year (in 1982 prices) in this sector over the next decade. This implies that real investment flows in the energy sector will have to increase substantially compared with past trends, rising from about 2 to 3 percent of GDP in the late 1970s, to an average of about 4 percent of GDP over the next decade. This chapter explains the basis for the estimates of investment requirements and examines the issues involved in mobilizing adequate resources, both in foreign exchange and in local currencies.

Investment Requirements

The bases of the projected increases in developing countries' energy demand and production were discussed in earlier chapters. These projections were prepared for individual countries taking into account their overall energy demand and economic growth prospects. In all countries, the projections assume a vigorous program to improve the efficiency of energy use and to develop indigenous energy resources which can be substituted economically for imported oil. However, the projected pace of indigenous resource development also takes into account the likely growth of markets and technical constraints. In particular, the projected development of gas resources is considerably below the technical production potential because gas markets take time to develop. Similarly, only those primary electricity and coal development projects which could be economically absorbed into the countries' energy supply systems have been included.

As shown in Table 5.1, nearly half of the estimated total investment requirement of \$130 billion per year, is needed in the power sector; and the share of power investments in GDP increases slightly over the 1980–95 period. This is due to two factors. First, though slower than the past trend, the anticipated growth in electricity demand (6.7 percent a year in 1980–95) continues to be higher than the projected growth of national incomes. Second, electric power investment requirements are rising because power facilities are becoming increasingly capital intensive as countries move away from oil-based generation. Whereas a large oil-fired plant requires an investment of about \$800 per kW (in 1982 prices), the investment cost of an installed kW of a large coal-fired plant is \$1,100 per kW (\$2,000 per kW for a small one) and over \$3,000 for some hydroelectric projects.

Investments in oil production also need to rise sharply, as increasing numbers of countries explore and develop their oil production potential; new oil finds are likely to be more expensive to develop than those developed in the 1960s and 1970s. A significant number of the investments in oil are needed simply to maintain current production levels and a reasonable ratio of reserves to production. The investments required for nat-

Table 5.1. *Commercial Energy Investment Requirements in Developing Countries, 1982–92*
(billions of 1982 dollars)

	Low income countries	*Middle income countries*		*All developing countries*	*Annual average, 1982–92*
		Oil importers	*Oil exporters*		
Electric power					
Hydro	74.4	132.2	31.8	238.4	21.7
Nuclear	6.3	40.8	6.1	53.2	4.8
Geothermal	0.1	4.3	2.1	6.5	0.6
Thermal	43.2	75.8	39.7	158.7	14.4
Transmission and distribution	49.9	101.8	49.9	201.6	18.3
Subtotal	173.9	354.9	129.6	658.4	59.8
Oil					
Exploration	21.2	48.9	99.1	169.2	15.4
Development	43.2	32.4	195.9	271.5	24.7
Other[a]	2.5	6.0	16.7	25.2	2.3
Subtotal	66.9	87.3	311.7	465.9	42.4
Refineries[b]	30.8	52.8	39.7	123.3	11.2
Natural gas					
Exploration, development, transmission and maintenance	17.5	16.8	30.2	64.5	5.9
Domestic distribution[c]	4.3	4.7	7.4	16.4	1.5
Exports	0.0	3.0	6.2	9.2	0.8
Subtotal	21.8	24.5	43.8	90.1	8.2
Coal	55.2	27.2	6.3	88.7	8.1
Total	348.6	546.7	531.1	1,426.4	129.7

Note: These estimates are for the investments required during 1982–92 to achieve the energy production levels set out in Table 3.1. Some additional investments amounting to $13 billion per year will be required in the 1993–95 period to complete the projects for 1995 production. Expenditures shown in this table do not include investments for fuel storage and retail distribution (except for pipeline investments for domestic distribution of natural gas) and for infrastructure associated with energy imports.

a. Includes maintenance of old fields, enhanced and secondary oil recovery, pipelines, and infrastructure.

b. Estimates include investments in refinery modifications necessary to achieve a balance between petroleum product supply and demand within developing countries, as well as investments in refinery rehabilitation and replacement of old plant and in energy conservation measures. These estimates could vary by as much as 20 percent, depending on assumptions concerning the refinery mix in China, and on the extent to which product imbalances in the developing countries are met through direct trade in refined products. Estimates exclude investments in infrastructural development, which amount to about $10 billion.

c. Distribution of gas from major transmission pipelines to residential and commercial users.

Source: World Bank estimates.

ural gas development are comparatively small and mainly to develop reserves already discovered. Overall, investments in the oil and gas sector will account for 39 percent of the total energy investments in developing countries over the 1982–92 period with the proportion being much higher for the oil exporting countries.

Coal projects planned in the next decade need relatively small investments and comparatively little foreign exchange, largely because 60 percent of the investment is in China and India, which have advanced mining and capital-goods industries of their own. Fuelwood investment requirements would amount to about $12 billion over the 1982–92 period, a low amount in relation to the importance of this critical resource.

The estimated cost of refinery investments over the period is about $123 billion; this excludes any provision for additional capacity for crude distillation. This estimate assumes that the bulk of the conversion facilities required to reduce petroleum product surpluses and deficits in developing countries will be installed in their own refineries. These estimates are highly sensitive to the future evolution of relative international petroleum product prices which will themselves be determined by the trends in world demand for the various refined products and by the magnitude of investments made for secondary refining capacity in the industrialized countries and

Table 5.2.. *Foreign Exchange Requirements for Commercial Energy Investments in Developing Countries, 1982–92*
(billions of 1982 dollars estimated annual average)

	Electricity	*Coal*	*Oil and gas*	*Total commercial energy*
Middle income countries				
Oil exporters	6.5	0.3	22.8	29.6
Oil importers	10.2	0.9	5.3	16.4
Low income countries	3.2	1.0	4.4	8.6
All developing countries	19.9	2.2	32.5	63.9[a]

a. Includes $9.3 billion for refineries, which is not included in country group or individual fuel totals.
Source: World Bank estimates.

in the high income oil exporters. Moreover, the economics of specific conversion projects vary greatly depending on site-specific factors and each conversion investment has to be viewed on a case-by-case basis.

The investments required over the next decade to achieve the potential energy savings in industry, discussed in Chapter 2, are estimated at $8 to $19 billion for short-term measures and an additional $48 to $86 billion for medium-term measures. About 40 percent of the investments required would be in oil importing countries; they have an average payback period of less than three years.[1] The short-term measures require small investments, mostly in improving combustion efficiency and steam system efficiency, insulation, and other housekeeping measures. The medium-term ones involve larger investments in retrofitting existing plants and adding to facilities. These figures relate to energy conservation measures only in existing plants and facilities. Interfuel substitution measures involving the installation of new, more efficient plants will require substantial additional investment.

Other investments, in improving the efficiency with which consumers use energy and developing geothermal and other minor sources of primary energy, are relatively small in global terms, although they may be large in individual countries and have an important role to play in the adjustment to higher energy prices.

1. As a group, the developing countries could save up to 38 million toe per year through short-term measures and an additional 80 to 120 million toe per year through medium-term investments.

Foreign Exchange Requirements

Of the total projected energy investments, about half ($64 billion a year in 1982 dollars) is estimated to be a direct foreign exchange cost. The foreign exchange content of energy investments varies by sector and by type of country. Oil and gas development and refining projects are generally high in foreign exchange (over two-thirds), as few developing countries can produce the necessary equipment. In coal, the projected foreign exchange share is low (about one-fourth) as the bulk of the investment is in countries with well developed domestic capital goods industries. In power, the ratio of foreign exchange to total costs is extremely variable. In countries with more advanced industrial sectors (for example, Brazil, China, India, and Yugoslavia), the ratio is as low as 5 to 10 percent. In some West African countries, by contrast, even hydropower investments may have foreign exchange components larger than 70 percent. In the aggregate, investments in electric power and coal projects, which together represent 52 percent of the total estimated energy investments in developing countries, will absorb only about 35 percent of the total foreign exchange financing required, or about $22 billion a year (see Table 5.2). The petroleum subsector, including refining, will absorb about 65 percent of the total foreign exchange requirements, or about $42 billion a year. Of the local currency required each year, about 70 percent ($46 billion equivalent) will be for power and coal projects, while 30 percent ($20 billion equivalent) will be for the petroleum subsector.

Excluding refinery investments, 54 percent of the foreign exchange requirements are for investments in middle income oil exporting developing countries, mainly for oil and gas; 30 percent in the middle income oil importers, mainly in electric power, but with a substantial amount in oil and gas; and 16 percent in the low income countries, with half of it in oil and gas because of the large petroleum development programs in China and India.

Reaching projected investment levels will require a continuation and, in some countries, an acceleration of the trend in the past decade during which energy investments rose significantly in relation to GDP. As energy investments are normally classified under several sectors in national accounts (mining, industry, transport, and infrastructure), it is difficult to compile data on the size and trends of these investments. However, studies of some major developing countries indicate that the share of energy investments in GDP has clearly been rising in the past decade. In some countries, such as Thailand and Turkey, total energy investments have as much as doubled their share of GDP since the mid-1970s; in other countries, such as Brazil, India, and Philippines, there have been very significant increases. As a rough approximation, one may estimate that the share of energy investment in GDP has risen from about 1 to 2 percent to about 2 to 3 percent during the last decade. The projections for the next decade imply energy investments averaging about 4 percent of GDP in developing countries. The ratio is somewhat lower for the low income countries than for the middle income countries, where commercial energy demands are growing more rapidly.

Achieving these rates of investment will require a substantial increase in the resources allocated for energy development both within the developing countries and from external sources. The remainder of this chapter discusses the scale of the efforts needed to mobilize these resources and identifies the actions that developing country policy makers and international financing agencies can take to mitigate the financing problem. But energy demand and, consequently, investments in energy production will be sensitive to the future evolution of energy (and particularly oil) prices. As indicated in Chapter 1, the energy demand and supply projections in this report are based on the premise that international oil prices in the early 1990s will be at least as high in real terms as they are today. Therefore, before turning to the specifics of how these large investments might be financed, it is useful to review the relevance of lower oil price assumptions to the economic profitability of these projects.

Sensitivity to Lower Oil Prices

On the basis of information available to the World Bank on the economic costs of alternative strategies for meeting the energy needs of developing countries, it is clear that investments of the magnitude identified in Table 5.1 constitute a satisfactory planning assumption. However, even if the equilibrium price of oil settles at a relatively low level (say $25 per barrel in 1982 dollars), the bulk of the projected energy investments would still be advantageous to developing countries.

In electric power, the economic merits of generation investments must be examined in the framework of a long-term plan for system development. Assuming reasonable values for key parameters (particularly the cost of capital), the development plan compares the costs of several options for meeting the projected demand for electric power. Given the wide variation in the costs of hydropower projects, and the fact that some sites are marginally economic even at current prices of oil, some hydro developments will become uneconomic at lower oil prices. However, as most of the larger hydro projects have relatively lower unit costs, the aggregate capacity affected by a drop in oil prices to $25 per barrel would be small in relation to the total additional capacity projected. In thermal generation, the economics of alternatives to oil would not be greatly affected by a drop in oil price to this level, with the possible exception of thermal generation projects based on the development of low-grade lignite deposits which are highly capital intensive and subject to some technical risks.

The economics of petroleum investments are evaluated mainly in relation to the price at which the relevant petroleum products can be traded. In the oil exporting developing countries, there is little question that projected oil investments would result in incremental production at costs well below the export value of oil. Even in oil importing developing countries, where exploration and production costs are generally higher than in exporting countries, the investments will continue to yield satisfactory economic returns at a significantly lower oil price. For example, in six major OIDC oil producers, which account for over 75 percent of the oil produced by this group, the costs per incremental barrel of oil production are in the range of $10 to $20—that is, well below the projected costs of imported oil. As shown in Chapter 3, the long-run marginal cost of natural gas production in developing countries is so far below the price of its oil substitutes that there is little doubt about the economic benefit of its exploitation provided there is a market for its use.[2]

The refinery investments shown in Table 5.1 consist mainly of modifications of existing refineries which, as explained in Chapter 3, are sensitive to the price differential between residual fuel oil and middle distillates rather than to the absolute level of crude oil prices. As such, their economic merit will be affected by policies concerning the domestic prices of petroleum products (especially the subsidization of diesel and kerosene) and the pace of fuel oil replacement rather than the projected crude oil price. Investments to increase the fuel efficiency of refineries are sensitive to the oil price assumptions, but are expected to be economic at significantly lower oil prices as well.

As the bulk of the coal investments are in China and India, where production costs are low in relation to oil prices, there is little question regarding their net economic benefits. However, at the margin, there are probably some coal developments involving large infrastructure investments which may turn out to be uneconomic if oil prices remain relatively low.[3] Finally, the high rates of return and quick payback periods associated with the great majority of energy efficiency and retrofitting projects ensure their continued viability at substantially lower energy costs.

2. Market limitations have been taken into account in projecting the production of natural gas and the related investment requirements.

3. It is worth noting that investments involving the establishment of infrastructure for the import of coal may well be uneconomic if the oil price drops significantly. However, this category of investments is not included in Table 5.1.

External Financing Issues

The increased allocation of developing countries' resources to investment, particularly in the energy sector, has been paralleled by increased flows of external capital. During the 1960s and early 1970s, there was no major shortfall in the supply of foreign exchange for energy investments, which for most developing countries, consisted mainly of power utilities' investments.

Recent Trends

However, this pattern changed dramatically after 1973 as developing countries stepped up their external borrowing in all sectors, and particularly in energy. As summarized in Table 5.3, the total amount of publicly guaranteed external borrowing for energy investments in developing countries increased in real terms (1982 dollars) from $9.7 billion in 1975 to $15.8 billion in 1980. These data come mainly from the Debt Reporting System of the World Bank and relate only to publicly guaranteed debt.[4] Nevertheless, they serve to illustrate the rapid increase in energy financing that occurred over this period.

The fastest increase was in lending from private commercial sources, whose publicly guaranteed energy lending to developing countries rose by over 150 percent in this period. By 1980, these sources along with export-related financing accounted for 68 percent of the developing countries' external borrowing for energy. Multilateral institutions also doubled their energy lending, and their share of the total energy borrowing by developing countries rose to 23 percent by 1980. In contrast, the share of concessional aid from bilateral agencies decreased substantially over the period as their volume of assistance remained roughly unchanged in real terms. At the same time, however, it is worth noting that the energy sector has been the fastest growing area in many bilateral aid programs and its share in these programs rose substantially in the second half of the 1970s (see Box 5.1).

4. The system covers flows from the following sources: multilateral lending institutions, bilateral aid, export-related credits (suppliers' credits, fixed-term private financial, and bilateral nonconcessional flows) and financial institutions' loans at floating rates. Bond issues are excluded.

Table 5.3.. *External Borrowing in Developing Countries for Energy, 1975–80*
(billions of 1982 dollars)

	1975		1980		Total, 1975–80	
	Dollars	Percent	Dollars	Percent	Dollars	Percent
Source						
Export related[a]	4.3	44	5.2	33	37.5	39
Financial institutions[b]	2.1	22	5.5	35	35.2	36
Multilateral[c]	1.8	19	3.6	23	15.5	16
Bilateral concessional[d]	1.5	15	1.5	9	9.1	9
Total	9.7	100	15.8	100	97.3	100
Subsector						
Coal	0.2	2	0.7	4	2.7	3
Oil and gas	3.0	31	3.8	24	24.9	25
Power	6.5	67	11.3	72	69.7	72
Total	9.7	100	15.8	100	97.3	100

Note: Based on data from the World Bank's Debt Reporting System (DRS), which includes only publicly guaranteed debt as reported by countries to the DRS.

a. Includes suppliers' credits, fixed-term private financial loans, and bilateral nonconcessional loans. Fixed-term commercial and nonconcessional bilateral loans are assumed to be export related, mainly buyers' credits.

b. Publicly guaranteed floating rate private commercial loans.

c. Asian Development Bank, African Development Bank, Inter-American Development Bank, European Investment Bank, and World Bank.

d. Canada, France, Federal Republic of Germany, Japan, OPEC bilateral, United Kingdom, United States, and others.

Source: World Bank.

In terms of energy subsectors, the aggregate pattern of external financing has reflected the historical structure of investment requirements, with the electric power subsector accounting for 72 percent of the total external borrowing between 1975 and 1980. However, as shown in Table 5.4, the contribution of individual financing sources varies strongly across the different energy subsectors. The bulk of the flows for oil and gas development were in the form of export-related credits and commercial flows. Most of the energy lending by multilateral and bilateral agencies has been for electric power. In part, these patterns reflect the longer history of oil and gas financing by the commercial agencies, but they also reflect the fact that different financing sources have directed their efforts to very different groups of borrowing countries.

Table 5.4. *External Borrowing for Energy by Source and Sector, 1975–80*
(billions of 1982 dollars)

	Coal		Oil and gas		Electric power		Total	
Source	Dollars	Percent	Dollars	Percent	Dollars	Percent	Dollars	Percent
Export related[a]	1.31	3.5	10.73	28.6	25.51	67.9	37.55	100
Financial institutions[b]	0.97	2.8	11.55	32.8	22.67	64.4	35.19	100
Multilateral[c]	0.42	2.7	1.17	7.6	13.86	89.7	15.45	100
Bilateral concessional[d]	0.06	0.7	1.43	15.6	7.65	83.7	9.14	100
Total (Average)	2.76	(3)	24.88	(25)	69.69	(72)	97.33	(100)

Note: Based on data from the World Bank's Debt Reporting System, which includes only publicly guaranteed debt as reported by countries to the DRS.

a. Includes suppliers' credits, fixed-term private financial loans, and bilateral nonconcessional loans. Fixed-term commercial and nonconcessional bilateral loans are assumed to be export related, mainly buyers' credits.

b. Publicly guaranteed floating rate private commercial loans.

c. Asian Development Bank, African Development Bank, Inter-American Development Bank, European Investment Bank, and World Bank.

d. Canada, France, Federal Republic of Germany, Japan, OPEC bilateral, United Kingdom, United States, and others.

Source: World Bank.

Box 5.1. *Official Lending for Energy Investment*

The World Bank is the largest and most diverse multilateral lender for energy; its commitments nearly quadrupled during 1975–81 totalling $10 billion in that period. Commitments from the other main multilateral institutions also increased more than threefold in the same period to a total $6.7 billion. OPEC multilateral agencies also increased their energy project lending, with total commitments of $1 billion over the period. (This information is based on figures published by the OPEC Fund.) The share of energy in the total operations of the multilateral agencies in 1975–81 ranged from 46 percent for the OPEC Fund, 27 percent for the Inter-American Development Bank, 25 percent for the World Bank, to 9 percent for the African Development Bank.

Commitments of concessional bilateral assistance for energy rose from $500 million in 1975 to some $2 billion in 1980. Though bilateral assistance for energy has risen more slowly than other public external capital, energy has been the fastest growing area in many bilateral aid programs. For the Development Assistance Committee members (including the European Economic Community), the share of energy in total aid programs increased from 3.5 percent in 1975 to 8.5 percent in 1980 (see table below). Over the 1975–80 period, Germany, Japan, OPEC, and the United States accounted jointly for over 75 percent of total concessional bilateral financing for energy investment in developing countries.

Commitments of Bilateral Concessional Assistance for Energy, 1975–80
(millions of dollars)

Donor	*Dollars*	*Percent*	*Energy as percentage of donor's total*
Canada	366	5	23
France	249	3	8
Germany	879	12	11
Japan	2,125	28	25
United Kingdom	41	1	7
United States	1,057	14	7
OPEC bilateral	1,622	22	12
Other	1,162	15	..
Total	7,501	100	..

.. Not available.

Source: World Bank Debt Reporting System. Figures may differ from those of other sources as a result of differences in project and financing classification.

Multilateral Commitments for Energy, 1975–81
(millions of dollars)

	1975	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*	*Total*
Asian Development Bank	153	147	217	249	325	385	480	1,950
African Development Bank	19	13	27	28	64	52	32	235
Inter-American Development Bank	270	288	407	923	397	416	935	3,636
European Investment Bank	26	90	41	48	188	348	140	881
Subtotal	468	538	692	1,248	974	1,201	1,687	6,702
World Bank	584	1,009	1,102	1,156	1,467	2,849	2,233	10,400
Total	1,052	1,547	1,749	2,404	2,441	4,048	3,820	17,102

Source: Annual Reports.

As shown in Table 5.5, the low income countries are much more dependent on multilateral and concessional bilateral flows for the external financing of energy projects—drawing from them 79 percent of their total, public external borrowing for energy. In contrast, middle income countries obtained about 80 percent of their external borrowing for energy in the form of export-related and private financial flows.

This analysis also emphasizes the differences between the traditional roles of private sources and export financing on the one hand, and multilateral and concessional bilateral funding on the other. The commercial financial institutions lend almost exclusively to the middle income countries, as they are more capable of servicing external debt on market terms. As the international orientation of commercial banks is also influenced by the activities of their major corporate clients, they lend more for oil and gas in projects where international oil companies are involved. In contrast, multilateral agencies and bilateral

Table 5.5. *External Energy Borrowing, by Source and Country Income Group, 1975–80*
(percent)

	Low income	Middle income: Oil importers	Middle income: Oil exporters	All developing countries
Export related	16.5	38.1	42.6	37.9
Financial institutions	4.3	40.4	40.2	37.1
Multilateral	46.7	16.5	7.0	15.5
Bilateral concessional	32.5	5.0	10.2	9.5
Total (percent)	100.0	100.0	100.0	100.0
Total (billions of 1982 dollars)	8.76	50.41	37.83	97.33[a]

a. Due to rounding errors and minor data discrepancies, the sum of individual country group figures differs slightly from the total.
Source: World Bank, Debt Reporting System.

concessional flows are the major sources for the low income oil importing countries, which account for about 30 percent of these institutions' energy lending to developing countries.

Prospects and Constraints

A comparison of the projected foreign exchange requirements for energy development in the developing countries with the recent flows of external financing for this sector clearly illustrates the foreign financing problem facing these countries in the coming decade. Even if some allowance is made for the addition of nonguaranteed debt and for direct private investment (mainly by the international oil companies), as well as for some real growth in official flows since 1980, it is unlikely that the total volume of external flows for energy development to the developing countries has exceeded $25 billion in 1982. Against this, the projected amount of foreign exchange required for energy investments is estimated to average $64 billion a year (in 1982 dollars) over the 1982–92 period. Hence, in order to meet the estimated foreign financing requirements over the next decade, these external flows will need to expand by about 15 percent a year in real terms. To some extent, financing can be redirected to energy from other sectors. However, as energy is rapidly becoming a major component of external capital flows, such diversion has its limits and additional energy financing will require an overall expansion in capital flows as well.[5]

While the mobilization of adequate external financing will be a major concern for all developing countries, the issues involved are likely to differ for individual fuels and country groups. The low income countries' foreign exchange requirements are about 16 percent of the total for all developing countries. This group of countries received only 9 percent of the flows of publicly guaranteed external credits for energy during 1975–80. And, as the flow of nonguaranteed capital and direct investment is likely to be skewed toward middle income countries, the low income countries' share in aggregate flows of external capital is likely to be well below 9 percent on the basis of current financing patterns. This implies a significant financing gap. Though the gap is partly due to the inclusion of China in the estimates of financing needs, it reflects the perennial scarcity of external financing in low income countries, which have to rely on multilateral and bilateral concessional flows for the bulk of their external borrowing.

Thus, the basic constraint on meeting the foreign exchange financing requirements of the low income countries is the slow expansion of official credits, particularly concessional flows that are suited to their overall debt servicing capacity. While commercial sources could finance some energy investments in these countries, their contribution will necessarily be constrained by considerations of creditworthiness. Further, more

5. Data on publicly guaranteed external lending commitments for 1975–80 suggest that energy accounts for about one-fourth of multilateral lending, one-tenth of bilateral concessional assistance, one-third of official export credits and one-fifth of private commercial flows to developing countries.

than three-fourths of the low income countries' external borrowing for energy during 1975–80 was for electric power, whereas over half of their foreign exchange needs over the next decade will be in the petroleum sector. Hence, their traditional lenders need to reorient their lending to meet this need.

For the middle income countries too, there is a need to reorient external capital flows from a heavy emphasis on the power sector towards a larger share for petroleum. The projected foreign exchange requirements in the power sector, while higher than current flows, are relatively small in relation to the total cost of those projects. Official credit agencies have a strong interest in financing power investments (and especially those in nuclear facilities), as these stimulate equipment exports. Further, these institutions generally have better established procedures for financing power investments than for petroleum. Therefore, the principal constraint in power sector development is likely to be the financing of local costs.

The external financing needs of coal projects are small compared to their total costs and to overall energy sector investment requirements. Traditional sources should be able to provide most of the external financing required, but in countries with large coal investment programs (such as China, India, Turkey, and Yugoslavia) an important issue will be the willingness of governments to allocate the necessary foreign exchange to the coal sector within the country's overall debt limits.

In the oil and gas sector, a quantum increase over current flows is required. About 70 percent of the required investment (or about $23 billion per year) is in the middle income oil exporting countries. In this group of countries, projects which are export oriented and have satisfactory returns will face relatively little difficulty in securing equity financing, provided political risks are not too great. However, the financing of projects in the oil importing developing countries will pose a major problem. Their estimated foreign exchange requirements of $10 billion per year for oil and gas projects are about equal to the current publicly guaranteed financing flows for the whole energy sector in these countries. Given that the bulk of this borrowing has been for the power sector in the past and the fact that these countries are likely to have received only a small share of the direct private investment by international oil companies, it is clear that the proposed investment levels are unlikely to be achieved without substantial expansion in the financing provided by all the important actors in this area. International oil companies need to expand their efforts and to broaden their scope of operations into the smaller and newer producing countries. Governments will need to supplement these efforts in areas where private sector activity alone is likely to be too slow or inadequate, notably in projects oriented to meeting domestic consumption requirements, particularly in gas exploration and development. Official and commercial financing agencies will need to expand their support of the efforts by both international and national oil companies.

One method for mobilizing additional resources for energy development, and particularly relevant to the oil and gas sector, is to make increasing use of nonrecourse, or limited recourse, financing techniques. These techniques, which have so far been used in only a few instances in the developing countries, allow commercial lenders to finance attractive projects on the basis of the project's own reserve base, production profile, or other characteristics, rather than on the basis of overall guarantees offered by the host government or the project owners. The required conditions for successful project financing of this nature include a reasonable perception of country and project risk, a strong and internationally recognized project sponsor and preferably an export orientation of the project. These conditions are unlikely to prevail for a large number of projects, making this form of financing of limited applicability in developing countries, particularly those that import oil. Nevertheless, a special effort should be made to explore these techniques where possible as a means of mobilizing additional external financing.

On the whole, new commitments from export credit agencies and commercial financial institutions are now severely restricted by borrowers' degree of creditworthiness. The same considerations may also restrict developing countries' ability to attract direct foreign investment. For middle income countries whose creditworthiness is in question, as with low income countries, expansion of multilateral and bilateral energy lending will be necessary to finance an expanded investment program.

For some of the countries now regarded by commercial lenders as poor risks, key investments in the energy sector could transform the balance of payments outlook. However, to achieve this, they will need significant additional external borrowing. Breaking this vicious circle will require close consultation and cooperative action among several concerned parties: first, the multilateral financing agencies, which can analyze creditworthiness in a longer-term perspective and evaluate the economic impact of different investment programs; second, the commercial lenders who have greater financial resources but may be reluctant to invest them in long-term obligations in countries that face balance of payments difficulties in the short or medium run; third, the governments in the capital surplus and industrialized countries who must evaluate the need to increase the resource base of the multilateral financing agencies and their programs for energy lending; fourth, the international oil industry, which must be induced to deploy a larger share of its enormous financial and technical resources in developing countries; and finally, the developing countries, which must undertake the necessary improvements in the management of their economies and, particularly, the energy sector.

Domestic Resource Mobilization

Roughly half the projected investment requirements in the energy sector are for local resources, with the share being even higher in some subsectors, such as electric power and coal. Given the parallel external financing problem, discussed earlier, it is essential that developing countries take measures to generate a large portion of these resources locally. The exact magnitude will vary according to individual country circumstances, but in all countries, the availability of domestic resources may be the decisive factor in the success or failure of energy investment programs. Many developing countries have difficulty mobilizing domestic resources for energy investment, partly because domestic savings in general are too low and partly for reasons specific to the energy sector.

As noted in Chapter 4, the energy sector in developing countries is dominated by public sector companies. These enterprises have, to varying degrees, been beset by the same problems—too little managerial autonomy, cumbersome procedures, uncompetitive salaries, and so forth—that generally afflict the public sector in developing countries. These problems have serious implications for the financial viability of energy enterprises and their ability to mobilize domestic resources for investment.

During the 1960s and early 1970s, most power utilities met a satisfactory portion of their investment requirements from internal sources. Power tariffs fully covered costs and external borrowing was used to finance foreign exchange requirements that were as high as 50 percent to 70 percent of investment costs. Since then, the finances of most power companies have deteriorated severely. Sharp increases in fuel and borrowing costs have not been matched by increases in tariffs. And the investments now being contemplated have longer gestation periods and much higher costs requiring loans with longer maturities than are generally available. Reliance on budgetary support for financing power investment means that investment has to be restrained when macroeconomic pressures on the budget become severe. Inability to raise domestic financial resources has delayed the implementation of power investments in many countries, leading to severe shortages of power (for example, in India and Turkey), and heavy economic losses due to the disruption of production.

The growing financial strains on power utilities mean that greater attention must be paid to the following key factors influencing their financial viability:

- *Power tariffs*. In most utilities, power tariffs are below the long-run marginal costs of supplying power, in some cases by very sizable margins. In addition to its economic impact, underpricing electricity critically impairs the operating revenues of utilities and forces them to undertake additional borrowing that imposes a heavy debt service burden in later years. Many national power companies now need to increase their tariffs by 60 to 80 percent to regain their long-term financial balance and to bring down their borrowing requirements to more manageable levels. Governments' unwillingness to raise tariffs in line with costs stems both from the political unpopularity of these measures and the mistaken conviction that curbing utilities' tariffs helps to control inflation. Recent tariff increases in most developing countries have been granted on a haphazard basis, to overcome utilities' immediate difficulties, rather than to ensure their long-term financial equilibrium and provide the basis for financing needed expansion.

- *Operational inefficiency.* The growth of revenues is also held back by technical inefficiencies that do not permit plants to be fully utilized and cause heavy losses in the transmission and distribution of power. Bad metering and poor collection of bills add to these problems; unpaid bills exceed six months of revenues in some cases. Even when tariff levels are adequate, uncollected bills payable by governments and other state enterprises often are a serious problem, and one that cannot be resolved without budgetary intervention, especially when the situation has been allowed to deteriorate for many years.
- *Financial structure.* Capital contributions from the government are sometimes not forthcoming when due, and utilities, therefore, have to rely to a greater extent on money borrowed at high rates of interest.

Coupled with the inadequacy of domestic capital markets in developing countries, these difficulties in generating cash may force utilities to borrow foreign exchange to meet local costs. In view of the scarcity of external capital, it would clearly be inappropriate to borrow abroad for local costs without first having assured a maximum effort to raise the resources domestically, which must include an appropriate tariff structure to provide for a reasonable degree of self-financing within the sector. Shortfalls in local cost financing have led some governments (Colombia's, for example) to attempt to create new sources of medium- to long-term local financing, or to increase loans or equity injections from the public budget to national companies.

National oil companies typically suffer less from management constraints than do power companies. However, the financial viability of oil companies is often endangered by governments' regulation of consumer prices. Most national oil companies are integrated through exploration, development, refining, and marketing. In exploration and development, they have the characteristics of a commercial company. At the same time, they must sometimes sell oil and gas at prices regulated by the government and held below costs. Losses incurred on subsidized domestic marketing and refining operations have a direct impact on these companies' overall profitability and, therefore, on their ability to generate investment capital. Often, exploration and production expenditures are the first to be affected by overall profitability and liquidity problems.

National oil companies have, like public power utilities, suffered the effects of delays in payment from government agencies, particularly from funds designated to stabilize prices, or to cover the price differential between international and domestic markets. Serious liquidity problems have resulted from this source in Portugal, Thailand, and Turkey, among other countries. In some developing countries, the state is involved in all stages of oil exploration and production but functional companies have been less integrated and, therefore, able to generate a surplus on individual stages of the operation. This is the case in both China and India where production companies have sold crude at regulated domestic prices, but prices have been adequate to cover production costs and to enable the entity to finance a reasonable portion of its investment program. With this arrangement, subsidies at the retail level have not affected investment by production companies.

National oil companies are also an important source of tax revenue for the national budget through generation of export earnings, royalties, other production-related taxes, and corporate income taxes. While it is appropriate to tax natural resources, particularly oil and gas, which have a high rent element, in some cases overall levels of taxation have been excessive and inflexible.

Such was the case of Bolivia, where a 100 percent "windfall" tax was levied on all profits above a defined per-barrel limit, resulting in a severe reduction in cash flow to the national oil company and curtailment of its investment program. Peru's oil company was for a period liable for all of the tax obligations of foreign contractors producing oil in the country. As production levels increased, the NOC was faced with a large tax burden, inflexible and unrelated to its own operations, and not deductible from overall corporate tax liabilities. Before this system was modified, it severely reduced the national company's profitability and ability to generate needed surplus for investment.

For coal, the issues are somewhat different since domestic resource mobilization is the critical problem. During the 1960s and 1970s, only a few countries (such as China and Yugoslavia) set domestic coal prices to allow companies a reasonable return on investment. Generally, domestic coal prices were heavily subsidized, often not covering even cash operating costs. As a result, cash generation for investment needs was extremely limited and coal companies depended primarily on government loan and equity funding through annual budget allocations. Since 1980, a number of countries have taken steps to adjust domestic coal prices towards border prices (Indonesia and Philippines, among them) or at least to ensure that more cash is generated (India and Turkey, for instance). Clearly the financing needs of the proposed coal expansion programs will not be met unless prices are radically increased.

Experience with private financing of coal development is rather limited. The private coal industry in Brazil relies on government funding for a major part of its cash generation; only in Colombia, the Philippines, and Zimbabwe is private resource mobilization for coal development taking place, albeit on a limited scale (5 to 10 million tons over the decade). In all these cases, private financing must be supported by economic pricing policies.

Conclusions

A substantial increase in energy investments is economically justified and is necessary to meet the growing demand for commercial energy in developing countries. The financing problems, both external and domestic, are formidable and call for a maximum effort by all concerned agencies to increase the availability of financing for economically justified energy investments. The analysis of the financing issues in this Chapter suggests the following conclusions:

- Increasing domestic resource mobilization in developing countries is of paramount importance. To a significant extent, this can be achieved within the energy sector by following appropriate pricing policies. The tariffs of power companies must be brought into line with the long-run marginal costs of supply, and maintained at this level with frequent, systematic adjustments compensating for inflation and fuel cost increases, to permit the companies themselves to finance a reasonable proportion of their expansion needs and to service their borrowings, while preserving a suitable financial equilibrium. Pricing coal and petroleum at their economic opportunity costs should normally ensure that publicly owned coal and oil companies are able to generate operating surpluses, which can help to meet their growing investment requirements. The urgency of improving domestic resource mobilization is underlined by the present acute scarcity of external lending, which makes it inappropriate to rely on external financing of domestic costs, except in unusual circumstances.
- The large foreign exchange financing gap and the widespread limitations on new commercial lending commitments, because of the growing number of countries that have debt servicing problems, makes it vital that official credit institutions should be able to expand their lending. A major priority should be to lend to countries that have limited access to commercial finance and, to the extent possible, to play a catalytic role in mobilizing additional external finance for priority investment projects. This will apply particularly to power investments in countries where the import content is high, but commercial financing is difficult.
- Official credit institutions—multilateral, bilateral, and export credit agencies—should

become more active in petroleum financing, and focus available resources on the investment needs of oil importing developing countries. A substantial increase in their resources for this purpose would be easily absorbed in investments that have a high return and would bring a structural improvement in those countries' balance of payments. To facilitate this, national oil companies may have to package their financing requirements as specific projects, rather than relying on balance-sheet borrowing. Official lending for petroleum projects should be directed largely to projects oriented towards domestic markets, since these may not attract international equity participation.

- A determined effort must be made both by international financial institutions (official and commercial) and by the concerned developing countries to encourage the use of project or nonrecourse financing techniques whereby a greater portion of their oil development program can be financed without resorting to sovereign risk debt.
- In oil and gas, the foreign exchange financing gap cannot be filled unless flows from the whole range of possible sources of finance are increased. In particular, developing countries should make a determined effort to draw on the resources of the international oil companies. If OIDCs can attract even a small share of these companies' expenditures, their financing problem would be significantly alleviated. Multilateral agencies can play a useful role in attracting such flows to countries or projects that might otherwise be less attractive.

6. The Role of The World Bank

The World Bank has accorded a high priority to energy in its overall program because of the critical impact of adjustments in this sector on the overall structural adjustment and growth prospects for most developing countries; because of the massive needs for financial and technical assistance to complete the process of adjustment in the energy sector; and because of the contribution that the Bank can make in terms of financial support, policy advice, institutional strengthening, technology transfer, and improved project selection, design, and implementation.

The energy sector in developing countries will absorb a large and growing share of total investments, doubling from about 2 to 3 percent of GDP in the late 1970s, to an average of 4 percent of GDP over the coming decade. These investments combined with a vigorous effort to improve the efficiency of energy use should enable the oil importing developing countries to reduce their expensive dependence on oil imports which, in 1980, absorbed a quarter of their aggregate merchandise export earnings and much more in many countries. Successful implementation of the energy strategies outlined in this report could lead to a lowering of this figure to about 11 percent by 1995, assuming that oil prices stay at their current level ($29 per barrel) in real terms. Thus, energy policies will have substantial macroeconomic implications and will, to a large extent, determine the success of the overall process of structural adjustment in the developing countries.

The analysis in this report has demonstrated that the developing countries' adjustment to higher commercial energy costs is far from complete. Despite the major shifts in pricing structures, investment programs, and economic policies that have already been accomplished in many of these countries, much more remains to be done to ensure that energy is used efficiently and to develop and utilize cheaper alternatives to imported oil.

To complete the adjustment process in the energy sector will require a major increase in the allocation of investable funds to the sector, both for energy production projects and for retrofitting programs to conserve energy. Generating the resources needed would be a challenging task under any circumstances, but it will be particularly difficult in the present international economic environment, when economic growth is likely to be relatively slow and external resource availability, both public and private, is likely to be constrained for the majority of developing countries. There is a real possibility that in some of these countries, particularly in the lower income ones which have limited access to commercial sources of finance, the adjustment to higher energy costs will be retarded by a shortage of investment resources. Finding the neccessary resources will be less difficult in the middle income developing countries, particularly those which are largely self-sufficient in energy or net exporters of it, but here, too, it will be a challenging and high priority task for energy policy makers.

A second prerequisite will be to strengthen the planning and management capability in the sector. The need to evaluate increasingly diverse and complex energy options, to develop sector investment programs, to solicit large volumes of investment finance from a variety of sources, and to conduct an effective technical and policy dialogue with potential private investors all require a much stronger national capability for energy sector management than exists in the vast majority of developing countries.

This twin emphasis on resource mobilization and strengthened sector management will also need to be reflected in the energy assistance programs of bilateral and multilateral agencies, including the Bank, which have an important contribution to make in these areas. Thus, while the remainder of this chapter deals with the Bank's response to these issues, many of the conclusions are equally applicable to other agencies which share the objective of supporting efficient energy development in these countries.

The principal objective of the World Bank's energy program is to assist developing countries to define and implement an appropriate development strategy for the energy sector. In response to the developing countries' changing priorities during the 1970s, the Bank significantly increased and diversified its energy activities.[1] Its energy lending increased and the Bank began to support the development of petroleum, coal, and other primary energy resources which it had not previously financed (see Table 6.1). This process was supported by a substantial strengthening of the Bank's technical and economic staff with energy expertise. It also led to a growing emphasis on the better management of energy demand and on providing technical assistance to developing countries in the evaluation of major energy issues and options. In collaboration with the UNDP, the Bank embarked upon a 60-country program of energy sector assessments designed to diagnose the main energy issues in the countries studied and to serve as a framework for investment and policy decisions by governments and external aid agencies (see Box 4.3). As part of its project financing activities, the Bank stepped up its efforts to function as a catalyst in mobilizing additional funds for energy development from private and public capital sources.

1. The evolution of this program can be traced in a number of energy policy papers which were approved by the Bank's Board of Executive Directors. The more important of these include *A Program to Accelerate Petroleum Production in the Developing Countries*, January 1979; and *Energy in the Developing Countries*, August 1980.

The Bank now has a large and diverse energy lending program and is a major source of policy advice and technical assistance to its borrowers. It uses a variety of instruments to provide this assistance, including financial support for energy development projects; technical assistance in evaluating national energy options and priorities and in carrying out preinvestment studies; management assistance at both the agency and sectoral levels; and an ongoing dialogue on important energy issues as part of its overall economic work. Although these activities are often carried out as discrete tasks, a distinguishing feature of the Bank's involvement is an emphasis on ensuring that all these elements are part of an integrated strategy and a long-term commitment to improving the energy prospects of developing countries. Thus, in each country the specific components of the Bank's energy program are consistent with the energy sector priorities and the broader development context of that country.

Resource Mobilization

The Bank's direct contribution to mobilizing resources has been a substantial increase in its own lending for energy projects. This has grown substantially in recent years, doubling from $1.5 billion in fiscal 1979 to $3.4 billion in fiscal 1982 (see Table 6.1). Although this is still a small fraction of the total investment requirements for energy development in the developing countries, it has made the Bank the single most important official source of external capital for energy development in the developing countries.

Energy Lending

In the poorer developing countries, which have limited access to commercial finance, the $2.3 billion of highly concessional IDA financing provided during 1979–82 has made a major contribution to underwriting the process of structural change in the energy sector. As well as participating directly in energy financing, the Bank has made a major effort to mobilize resources from other sources. Within the countries concerned,

Table 6.1. *World Bank Lending for Energy, 1979–82*

	1979		1980		1981	
	No. of projects	*Millions of dollars*	*No. of projects*	*Millions of dollars*	*No. of projects*	*Millions of dollars*
Power	18	1,355	24	2,392	17	1,323
Coal	—	—	1	72	1	10
Oil and gas	4	112	13	385	12	650
of which:						
Exploration promotion	—	—	5	36	6	33
Exploration	—	—	3	96	3	70
Oil development	1	3	2	60	2	462
Gas development	3	110	3	194	1	85
Energy-related industry	—	—	—	—	1	250
Total	22	1,467	38	2,849	31	2,233

Note: Supplemental credits and loans are included in the lending figures but are not counted in project numbers. The lending figures, however, exclude fuelwood lending of $310 million during 1979–82.

adequate local resource generation has been addressed through the pricing and financial conditions attached to Bank loans and through the Bank's dialogue on sector issues with national policy makers. A special effort has also been made in the energy sector to mobilize additional external resources through cofinancing and through the identification of opportunities for direct private investment.

Cofinancing

The emphasis placed by the Bank on the cofinancing of its energy projects stems from three factors.

- The substantial investments needed for energy development in the developing countries require a major effort to mobilize funds from all potential sources.
- Projects in the energy sector are more likely to attract cofinancing than those in many other sectors because of the wide interest in energy development by both private and official financing agencies.
- Projects supported by the Bank are attractive to other lenders because they are assured that the project is carefully appraised from the technical, financial, and economic angles and because the presence of the Bank is seen to diminish risk.

During the period fiscal 1979–82, the $9.9 billion of Bank lending for energy was associated with another $11.2 billion of cofinancing from bilateral and other multilateral agencies, export and suppliers' credits, as well as commercial banks and private sources.[2] The "average" Bank energy project over this period had a total cost of $322.6 million with a foreign exchange component of 48 percent. As Table 6.2 shows, the Bank financed an average of 22 percent of the total cost (46 percent of the foreign exchange cost), while external cofinancing covered another 25 percent (51 percent of the foreign exchange cost). On average, therefore, the government or the local sponsor financed the entire local currency cost, plus about 3 percent of the foreign exchange cost of these projects. However, there are marked differences in financing patterns between types of projects, as well as among projects in the various energy subsectors. Predevelopment and engineering projects (with an average cost of $16 million) have a higher proportion of their cost in foreign exchange (72 percent average). Because of their higher risks, small loan amounts and the need for speedy implementation, these projects are not very attractive to many financing agencies and the Bank has financed a larger share of their total cost than is the case for development projects.

The highest degree of cofinancing has been in oil and gas development projects where every $1 of Bank financing was matched by $1.78 from other external cofinancers. The cofinancing ratios

2. These data are based on project financing plans at the time the projects were approved by the Bank's Board of Executive Directors.

1982		Total, 1979–82		Percent, 1979–82	
No. of projects	Millions of dollars	No. of projects	Millions of dollars	No. of projects	Millions of dollars
21	2,131	80	7,201	59	73
3	227	5	309	4	3
14	539	43	1,686	32	17
8	36	19	104	14	1
1	20	7	186	5	2
3	303	8	827	6	8
2	180	9	569	6	6
6	460	7	710	5	7
44	3,357	135	9,906	100	100

for the other energy subsectors were 1.28:1 for coal projects, 1.03:1 for power projects, and 0.95:1 for other energy projects (refineries, biomass, and so forth). However, in interpreting these cofinancing ratios, it is important to note that they are sensitive to the definition of the particular "project". In some cases, a narrowly defined project may be part of an integrated program of investments. In these instances, Bank finance may represent a relatively high share of a project's costs while remaining a relatively small share of the costs of the overall investment program. An example is the Bombay High project for oil development offshore India. The Bank's role here in technology transfer, reservoir engineering, institution building, and infrastructure development materially benefits potential investors and lenders who might be interested in the same field or in other parts of the program.

Cofinancing will continue to be an important feature of Bank projects, but two important caveats deserve mention. First, even if a project is highly successful in attracting cofinancing, a minimum participation by the Bank is necessary to ensure that the Bank's judgment is accorded due weight in decisions affecting the project, the subsector, and the sector. This is especially important in the energy sector because of the Bank's broad involvement in energy policy and the need to seek agreements with the government and concerned enterprises on sensitive matters affecting sector policy and institutional arrangements. It may sometimes be necessary to apply this criterion not only to the Bank's share of a whole project but also to its share in specific components of the project, to allow it to be closely involved in the project until completion. In such cases, the Bank may be required to finance a

Table 6.2. *Financing of World Bank Energy Projects, 1979–82*

		Percentage of total project cost		Percentage of foreign exchange cost[a]	
	Number of projects	Bank/IDA	Other external sources	Bank/IDA	Other external sources
Oil and gas	43	30	45	38	57
Predevelopment	26	65	8	88	11
Development	17	27	48	34	61
Power	80	23	24	53	54
Coal	5	20	25	32	42
All energy projects[b]	135	22	25	46	51

a. Financing of a share of local costs by external agencies can raise the total percentages in these columns above 100 percent.
b. Includes "other" energy projects.
Source: World Bank.

higher proportion of project cost in order to assure a project is completed satisfactorily. In other instances, where the basis for a sound policy dialogue has been established firmly, where significant progress has been made in formulating and implementing an energy policy, where institution building and technology transfer are proceeding well, and where the project is attractive to other financers—official or private—the Bank's share might be relatively low. Clearly, these conditions vary across projects and countries and any general guidelines on the extent of Bank participation have to be applied flexibly on a case-by-case basis.

The second caveat is that while individual projects may offer useful vehicles for mobilizing cofinancing, the decision on the appropriate pattern of energy development and financing is one that must be taken at the country level. In some countries, the overall foreign financing pattern and debt service ratios may be such that additional commercial financing should be limited and that, even after taking account of preferences of cofinancers, commercial borrowing for a particular energy project may not be desirable from a national viewpoint, even though it is feasible from the project or project executing agency's standpoint. Moreover, in a great many developing countries, the prospects for a substantial expansion in commercial bank lending for any sector are severely limited for lack of creditworthiness. The vast majority of lower income developing countries fall into this group but, as recent events have demonstrated, this constraint also applies to some of the middle income developing countries whose capacity to service a rising external debt is becoming increasingly strained. For this group of countries, attractive project economics will seldom override the limits imposed on commercial lending by the perceptions of country risk and creditworthiness. However, this is also the group of countries with the most pressing need to restructure their pattern of energy supply by developing indigenous energy resources. To help them achieve this important transition, the Bank and other official financing agencies will often need to provide a much larger share of energy project costs.

One feature which deserves greater emphasis in light of the very large investment requirements and the scarcity of external capital is project or nonrecourse financing. This will be promoted wherever possible as a way of mobilizing additional commercial finance. However, the conditions necessary for successful nonrecourse financing of energy projects (an internationally known and respected project sponsor, country perceived to be reasonably creditworthy and, preferably, an export-oriented project) are not commonly met. The scope for such financing is therefore likely to be limited in the near future but every effort should be made to expand it as rapidly as feasible. A review of all of the petroleum projects financed to date by the Bank shows that none of them would have met the conditions required for successful nonrecourse financing. In some cases (such as in the Ivory Coast), nonrecourse type financing may become a feasible option at a later stage in project development, but government-guaranteed borrowing (in which the Bank can assist) is initially necessary to develop the project to the point where it is an attractive candidate for additional nonrecourse financing.

Direct Private Investment

The Bank also promotes direct equity investments by the international energy industry in developing countries' energy supplies. The greatest potential for this is, of course, in oil and gas where the international petroleum industry has traditionally made an important technical and financial contribution. A variety of instruments are used by the Bank to pursue this objective. The Bank's exploration promotion projects are expressly designed to rekindle the interest of private companies in exploration and development by providing a better geological data base, rationalized and clearer incentive and contractual frameworks, and a stronger legal and institutional capability in the sector.

Other promotional vehicles also are used. Exploration drilling, reserve audits, and infrastructure financed by the Bank often have beneficial side effects. For example, the appraisal drilling in Tanzania induced further exploration by private companies which has resulted in the discovery of what could be a major gas deposit. Sometimes, infrastructure investments financed by the Bank encourage private involvement in exploration and appraisal. In Thailand, the Bank-supported gas pipeline has made it possible to develop small gas deposits situated adjacent to the pipeline (see Box 3.2). The Bank can also help in financing the share of national oil companies in joint ventures with international partners. There is now a growing body of evidence to indicate that international oil companies and the commercial banks prefer the national oil company of the host country to participate in their developing country projects, partly because this increases the perceived stability of the underlying contractual arrangements. However, many NOCs do not have ready access to the financial resources necessary for effective participation. By providing these, the Bank can help to overcome a frequent stumbling block in the development of joint venture projects (a project in Ivory Coast provides an example). Finally, the Bank may issue a "letter of cooperation", and assist in other arrangements to reduce the perception of political risk when asked to do so by the host government and the private investor concerned.

In addition to the activities undertaken directly by the Bank, its affiliate, the International Finance Corporation (IFC), is playing an expanding role in energy investments in developing countries. IFC was created to encourage the mobilization of productive private investment, both foreign and domestic. In this capacity, IFC not only makes loans for energy ventures, but has the unique ability to make equity investments directly in private sector projects. IFC has invested both equity and loans in oil and gas field developments, in enhanced oil recovery, the mining of coal, in power transmission, gas pipelines, ethanol facilities, and in domestic refineries. In addition, it has invested in gas utilization projects and has been instrumental in assisting the negotiation of geothermal power contracts and gas pipeline tariffs. IFC's continued expansion in the energy sector and its future strategy are an integral part of its new Five-Year Plan for fiscal 1984–88, already under discussion. These activities are viewed as an important complement to those of the Bank itself.

In addition to these specific instruments, the Bank also helps to encourage private investment in energy by identifying and discussing with national policy makers broader sectoral issues which may be acting as obstacles to this expansion. Producer pricing for gas and oil is a frequent subject of analysis, as is the country's overall approach to private energy investment and the allocation of prospective acreage between the private sector and the national oil company.

In carrying out this dialogue, the Bank's primary objective is to accelerate the pace of energy development in its member countries consistent with their broader development goals. The Bank fully appreciates the crucial role of the international energy industry in achieving this objective. However, its experience has demonstrated that in a number of circumstances, the priorities of the private sector may not match the priorities of an individual country. These circumstances, (discussed at length in Chapter 3), include the limited interest of international oil companies in developing small oil fields or gas resources, which have little export potential; the effect of the current cash constraints on the size of international oil company investments in exploration in the developing countries; the unwillingness of the industry to invest in countries perceived as high political or economic risks; or a simple divergence in the priorities attached to a particular energy development project by an industry with global investment options and by the country, for which this may be the only prospect for improving energy supply. These factors may necessitate the allocation of public resources to energy development in a number of countries. As a development institution, the Bank is ready to support these national efforts when it is convinced that they are an appropriate feature of the country's optimal sectoral and national development strategy.

Energy Sector Management

Along with its financial involvement, the Bank has made a major effort to assist its member countries in strengthening their management of the energy sector. In doing this, it has built upon its traditional strengths:

- Competent project selection, formulation, and implementation.

- Strengthening indigenous institutions and developing an effective sector planning and management capability.
- Analyzing key sector issues and helping the country formulate an appropriate overall sector development strategy.

Project Selection, Design, and Implementation

As well as requiring that projects have satisfactory economic rates of return and are part of the country's investment priorities, a traditional objective of Bank financing is to ensure that the projects it finances are well designed, are environmentally sound, incorporate technology appropriate to the circumstances, are implemented competently, and put into position an agency capable not only of implementing the project but subsequently of running and operating it. This is particularly important in the energy sector where technology is evolving rapidly, where many countries lack strong institutions, and where the cost of delay or wrong choice is high. The Bank's approach to project financing has, therefore, been qualitatively different from other financing institutions in its emphasis on a review of sector objectives, priorities, and investment options. Sometimes, this work leads to the selection of a project which had not previously been considered by the host country or had been rejected due to incomplete analysis. It can also identify priority investment opportunities which have not been taken up by other financing sources (such as international energy companies) because the investment, while attractive from the country's point of view, ranks low according to the global criteria used by them.

After a priority investment need has been identified, the Bank seeks to ensure that the project's design represents the least-cost solution. In the energy sector, this frequently implies an analysis of alternative development options for the supply system as a whole, because of the strong interlinkages and complementarities that exist among individual projects. The continued involvement of Bank staff throughout project implementation is particularly important in the energy sector because this sector now poses problems with which many developing countries are unfamiliar and which evolve over time. Regular onsite supervision of the project enables the Bank to help resolve technical problems, insist on continued budgetary support for agreed financing of local currency expenditures, and ensure that institutional arrangements are modified if necessary for the timely and cost-effective completion of the project. Bank staff also assist the borrower in identifying needs for external inputs, in preparing terms of reference for consultants used in project preparation or implementation, and in reviewing the consultants' qualifications and in evaluating their work. At all stages, the Bank seeks to ensure that the borrower's interests are safeguarded while, at the same time, bringing to bear on each decision an objective perspective and the experience it has gained in dealing with similar problems in other countries.

A key contribution by the Bank in the project context is the transfer of technology to the borrower. Special efforts are made to incorporate appropriate technology in the project design, not only to enhance project benefits, but to benefit the entire sector. Transferring technology is an underlying objective of a large number of Bank-financed energy projects. For example, while the Bank-financed hydrocarbon projects in China should strengthen the energy base by increasing oil production, they should also upgrade the technologies used in a wide range of oil field activities, such as those for acquiring and processing geophysical data, drilling, production, reservoir engineering, and enhanced oil recovery. The objectives and modes of technology transfer in Bank petroleum projects are discussed briefly in Box 6.1.

Institutional Strengthening

An equally important objective of the Bank is to strengthen indigenous sector management. At the project level, it helps governments to design implementation arrangements that create a core group of managers to maintain, operate, and expand the facilities provided under the project. To secure longer-term benefits, such as the development of stronger indigenous institutions (as in the Cairo gas distribution project), projects may have to be implemented more slowly than if, say, they were left in the hands of experienced, expatriate engineering contractors, but

Box 6.1. *Transfer of Technology in World Bank Petroleum Lending*

The transfer of technology in the Bank's petroleum lending starts with an objective assessment of the borrower's practices and capabilities and of the technical possibilities to improve them. This evaluation is usually carried out by Bank staff with considerable industry experience assisted by consultants. An important element of the transfer of technology in the petroleum industry, as in other project-oriented industries, is the strengthening of the managerial and engineering capacity for formulating and implementing projects, and for negotiating with potential suppliers of the capital goods, technology, and managerial resources needed for these projects. In its petroleum operations, the World Bank attempts to ensure that the technologies used are the most appropriate to the circumstances, both technically and economically. Borrowers are urged to accept external assistance if this is needed to avert costly problems in design and implementation.

Technology is transferred primarily through contacts between nationals and Bank staff and consultants in the course of training and on-the-job experience, and through the introduction of new technologies and associated equipment. The approach used by the Bank in project identification, conceptualization, and implementation, whereby experts in different fields typically work together, is novel in many developing countries. Moreover, the Bank's technical staff and consultants often lend considerable assistance in devising exploration strategies jointly with the borrower and in advising on the details of project design and engineering.

Training is one of the most frequent means of transferring technology. The China Daqing petroleum project is establishing two training centers, one to train yearly 2,000 skilled workers, and the other 500 professionals. Instructors, visual aids, electronic simulators, and technical materials are being drawn from industrial countries. In other projects, the training may include short courses or programs given abroad by the industry, consultant firms, and universities. There is also considerable scope in most projects for the less formal on-the-job training from Bank staff and consultants hired by the Bank or the borrowing country as well as from the suppliers of equipment and services during project preparation and execution.

The Bank reviews the equipment specifications prepared by the staff of the borrower or consultants in collaboration with the borrower, and normally requires that the import of equipment be coupled with appropriate maintenance and service contracts. Many of the techniques being used in the petroleum sector in developed as well as developing countries are extremely new, and some are used only by the individual international companies who developed and patented them. The Bank seeks to develop borrowers' abilities both to select technologies most suitable to their circumstances, recognizing the scope and limitations of the technologies, and to monitor their use, knowing the results that should be expected. Technologies which have been introduced through Bank-assisted projects include, for example, three-dimensional seismic surveys, drilling through high-temperature and high-pressure reservoirs, secondary and tertiary oil recovery, petroleum reservoir modeling, petroleum data banks, and financial reporting and management information systems.

with the benefit that they can be operated efficiently by indigenous staff thereafter. Many projects provide for training and technical assistance to address institutional weaknesses. Studies have been financed and systems put into place under Bank-financed projects for improving management information, budgetary control and accounting, and financial management. At the sectoral level, the Energy Sector Management Program provides a good example of a flexible and quick response to an emerging need for technical assistance identified through both project and sector work in these countries (see Box 4.4). This type of assistance is also being provided increasingly under the aegis of regular Bank-supported projects. The petroleum exploration and development projects financed by the Bank, for example, provide assistance in setting up an indigenous capability to negotiate contracts with international oil companies and monitor the petroleum exploration and development activities in the country.

Sectoral Issues

The integrative analysis of macroeconomic, sectoral, and project priorities is an intrinsic part of the Bank's work. This analysis and the ensuing dialogue with national policy makers covers a wide range of sectoral issues, such as the formulation of subsector strategies in oil, gas, coal or power, and specific issues such as demand management and pricing, environmental soundness, interfuel substitution, investment planning, resource mobilization, and the respective roles of public and private agencies in the development of the sector.

The Bank uses a variety of instruments for carrying out this work. Energy Assessment Reports and other sector studies are one vehicle for analyzing and discussing important sector issues with member governments. An important contribution of this work has been in helping to define "energy" as an integrated sector in many developing countries. By highlighting the interaction that exists among policies and programs in the various energy supply subsectors, they have served to identify previously neglected issues of coordination among the agencies responsible for these subsectors.

Another important vehicle for addressing broad sectoral issues is the involvement in successive investment projects in a particular subsector. At project appraisal and negotiation, the Bank often seeks agreements with the government, or the concerned energy enterprises, on issues of broad sectoral relevance as well as those affecting the project more directly. In energy projects, the pricing of petroleum, power, and coal is frequently discussed in detail and pricing objectives are set on the basis of an analysis of the economic and financial implications of alternative price structures. Specific remedial measures to improve the financial performance of the major energy supply agencies are also generally discussed and agreed with the borrower in the context of project negotiations. A good example of the contribution that can be made to the definition and analysis of sectoral issues through the vehicle of project financing is provided by the history of the Bank's involvement in the petroleum sector in Egypt (see Box 6.2).

Finally, in addition to sector reports and project work, the Bank influences energy policy in its member countries through the dialogue associated with structural adjustment loans, many of which have emphasized the restructuring of policies and programs in the energy sector. This emphasis is expected to continue because, for many developing countries, changes in energy supply and demand will effectively determine the success of their overall structural adjustment efforts.

The success of the Bank's efforts to assist energy development depends on two important factors. First, policy advice divorced from operational involvement is seldom as effective or as relevant as it needs to be; governments recognize this fact and demonstrate it in their receptivity to such advice. The policy advice that the Bank offers is accompanied by a financial commitment to underwrite a part of the investments required to overcome a difficult period of transition in the sector. This financial support both provides continuing participation and influence and allows the Bank to assist the line agencies to identify and resolve problems as they arise. It also serves to underpin the credibility of the Bank's advice, which is the second major factor underlying the success of its efforts. However, the high degree of credibility which the Bank enjoys in developing countries is not derived from its financial support alone, but has had to be earned over time. For example, when offering specific technical advice to energy supply agencies in these countries, the Bank's staff often have to persuade line managers that outside assistance is needed to improve their enterprise's operations in key areas. This requires a high degree of professional competence to ensure that the Bank's advice is perceived as well founded.

Future Energy Program

The analysis in this report confirms the need for massive energy investments by developing countries and the scope for the World Bank to play an important role in this effort. Although the Bank is the largest and most active agency lending for energy in developing countries, its lending is small relative to the investments required in this sector, and will continue to be severely constrained by resource availability. To ensure that lending for high priority investments outside the energy sector does not fall below acceptable levels, it has become necessary to limit the Bank's energy lending to about one-fourth of the total. On current assumptions regarding the overall level of Bank/IDA lending, the energy lending program is unlikely to exceed about $4 billion a year, on average, over the period fiscal 1983–87, growing in line with overall Bank lending. On this basis, the Bank's energy lending would amount to only 3 percent of the energy investments in the developing countries.

Box 6.2. *World Bank Assistance in the Petroleum Sector in Egypt*

The energy projects in which the Bank participates provide a vehicle for a broader dialogue on policies, investment priorities, and the analysis of sectoral issues. The Bank's participation in Egypt's petroleum sector is a good example of how this approach works in practice. In 1978, the Bank was invited to participate in financing facilities to gather, process, and transport gas, which would otherwise be flared, from the Gulf of Suez. This was a straightforward project with a high rate of return. However, it also provided an opportunity to review broader aspects of Egypt's hydrocarbon and energy sector development. This review showed that the government's forecasts of oil production were unattainable in the anticipated time frame. Further, stimulated by domestic prices that were a fraction of international prices, domestic oil consumption was a growing at a rapid rate, while some of the largest consumers of energy in Egypt were found to be the most wasteful. Clearly, an unchecked continuation of these trends would seriously erode Egypt's oil exports and affect its overall development prospects. A key element in preventing this appeared to be the rapid development of Egypt's gas potential: the country's annual gas consumption was less than 1 percent of its recoverable reserves, estimated at about 300 million tons of oil equivalent.

To better evaluate this option, the Bank has supported:

- An exploration study, based on existing data, for the Western Desert and the offshore structures around Alexandria. A subsequent Bank loan to support exploration in some of the structures that were identified by the study resulted in three separate discoveries. The study and consequent discoveries have stimulated the interest of the international oil industry in the Western Desert; Egypt has entered into a large number of production sharing agreements, and exploration has increased significantly.
- Two ongoing projects to develop, process, and transport offshore gas. On implementation, these projects would supply about half the gas produced in Egypt. The Bank has also helped finance a gas distribution project in Cairo to help substitute for higher value oil products like LPG and gas oil.
- An ongoing study to evaluate a pipeline network to transfer gas from surplus to deficit areas, which will also reduce the vulnerability of gas-based industries to production difficulties in individual gas fields.
- The design of a gas system for Upper Egypt based on natural gas from the Gulf of Suez and the newly discovered Red Sea fields. Gas from these sources would replace oil and, by replacing electric power, would raise the efficiency of energy use in a fertilizer plant by 300 percent.
- A study of energy pricing in Egypt. While only limited progress has been made in revising energy pricing to date, the country now has the necessary analytical framework to analyze the impact of discrete increases in energy prices on end products.
- An evaluation of the accounting and reporting system of the Egyptian General Petroleum Corporation (EGPC), to assist the company to upgrade its management and financial control. As a result, a comprehensive system for capital project accounting and control, planning and forecasting, and management information has been designed. EGPC staff are currently being trained to implement this system.

As a result of the Bank's involvement, the government now has at its disposal all the necessary elements to define and implement a long-term gas development strategy, with which natural gas could become a major source of domestic energy for Egypt during the 1980s.

Active involvement by the Bank in energy continues to be essential because of the priority the energy sector has in the developing countries, by the urgency of adjusting sector strategies, and by the very large volume of financing required by this sector in all countries. Bank financing plays an important catalytic role by attracting other investors and lenders to participate in high priority, economically sound, and financially attractive projects in all energy subsectors.

It is important that the Bank's energy activities continue to be diverse and responsive to developing countries' needs. Through project financing, technical assistance, and sector assessments, the Bank will endeavor to maintain its dialogue with member countries on sectoral policy issues; it will also provide assistance for sector management, institutional strengthening, and implementation of rational programs of investments, of demand management, and the commercialization of technologies particularly suited for developing countries which are unlikely to be developed elsewhere. The subsectoral composition of the Bank's energy lending and the content of its technical assistance activities will depend on the needs and priorities of individual countries, taking into account the availability of technical advice and financing from other sources, and the potential contribution the Bank can make not only in mobilizing financial resources but in a wide range of other dimensions.

Annex. Assumptions Used for Natural Gas Netback Studies

Estimates of netbacks are based on World Bank project data and a number of consultant studies using parameters from a range of specific cases. All projects were assumed to have a 20-year operating lifetime. The discount rate used in all estimates is 10 percent; higher discount rates would reduce some netbacks more than others, depending on the capital intensity of projects and the timing of their cost and benefit streams. The netback values are based on economic costs and benefits. The price projections used in the calculations (see table below) are expressed in mid-1982 constant prices and assume an annual real price increase for most fuels of about 2 percent after 1984.

In interpreting the netback values, it is important to note that these are measured at the "user's gate". Since gas transmission and distribution costs for different users may vary widely, the netback comparison at the wellhead may produce different values, or rankings for these uses. Moreover, as the lead times for developing the various gas using projects also varies considerably, it is important that the calculation of comparative netbacks takes this into account by discounting future cost and benefit streams both to the same point in time. Other end-use specific points are discussed below.

Price Assumptions Used for Natural Gas Netback Studies
(dollars per ton, constant mid-1982 prices)

	1982	*1985*	*1990*	*1995*	*2000*
Liquefied natural gas					
Crude oil (cif)	248	253	290	320	353
Fuel oil (cif)	185	193	221	244	269
Power[a]					
Fuel oil (A)	185	193	221	244	269
Fuel oil (B)	178	186	214	236	261
Distillate (A)	305	318	364	401	443
Distillate (B)	300	314	361	398	440
Imported coal (A)	104	106	114	122	131
Imported coal (B)	137	139	150	161	173
Lignite (B)	137	135	143	150	158
Residential distribution					
Kerosene (retail)	354	369	399	435	474
LPG (retail)	464	474	500	529	560
Fertilizers					
Ammonia	160	258	330	380	380
Urea	160	235	290	360	360

a. Based on two cases, (A) small power system with only thermal capacity, and (B) large power system with a mix of hydro and thermal plants.

POWER. The netback value of gas used to generate electricity is calculated as the difference in discounted total system costs over a 20-year planning period for system expansion plans optimized with and without supplies of natural gas. The results are presented for two cases: Case A protrays a relatively small system with only thermal capacity and Case B a larger power supply with a mix of hydro and thermal plants. The netback estimates include the value of fuel replaced by gas as well as the differential construction costs to optimize plant mix, which vary according to the fuel used. The range of figures in Table 3.4 is for a given system varying the size of gas using plants, with the quantity of gas supply changing from 20 MMCFD to close to 350 MMCFD.

FERTILIZER. The netbacks for integrated ammonia-urea plants are estimated for large plant sizes (around 500,000 tpy) located 2,500 miles from relevant export/import markets. The three cases cited in Table 3.4 reflect a range of construction and capital costs. Gas consumption starts three years after construction begins.

RESIDENTIAL/COMMERCIAL DISTRIBUTION. This sector consumes relatively small amounts of natural gas generally as a substitute for high-value

LPG and kerosene. It is assumed that the complete network would take nine years to construct. Consumption starts after the first year of construction and increases following an "S" shape curve to cover 70 percent of potential consumers over nine years. The results in Table 3.4 are for an oil importing country and, therefore, use cif prices for fuels replaced by natural gas. The study compares the costs and benefits of gas at the burner tip, and includes all household equipment costs attributable to natural gas. The range of figures is based on different urban population densities, types of housing, and total amounts of gas used. Residential gas use is most economic in new cities which require space heating and least economic in existing cities where gas is to be used largely for cooking. For existing cities, consumption is assumed to be 12 MCF per year per household for cooking and about 25 MCF per year if water heating is included; the addition of space heating increases it to a 40 to 70 MCF per year per household.

LIQUEFIED NATURAL GAS. The estimates take account only of economic costs and benefits, though different debt/equity ratios can cause significant differences in overall project profitability. In any LNG project, there is a close link between financing arrangements, the costs of equipment (often purchased from the country which is buying the gas), and the price of gas. As a result, it may often be difficult to ascertain the economic costs. The netback value takes account of all liquefaction, transport, and regasification costs. Present values of cash flow streams are calculated as of the year construction begins. Within the range of plant sizes studied (300 to 500 MMCFD), there are small differences in netback values; however, there are diseconomies of scale in systems with smaller capacity than this. Netback values are more significantly affected by location, and particularly by the presence or absence of infrastructure. In the example considered, the absence of preexisting infrastructure would raise construction costs for a liquefaction plant by about 50 percent. Lastly, LNG netback values are strongly influenced by the assumed value of gas delivered in the consuming country: if the price of gas is tied to the cif price of fuel oil in the consuming country, as has been done for the the estimates in Table 3.4, netbacks are lower than if the price is tied to that of crude oil.

World Energy Indicators

Contents

1 Basic Indicators

Country	Population, mid-1980 (millions)	GNP per capita, 1980 (US dollars)	Average annual growth rate, 1970–80 (percent): GDP	Average annual growth rate, 1970–80 (percent): Industry	Industry as percentage share of GDP, 1980	Net fuel exports (imports) as a percentage of: Total merchandise imports, 1980	Net fuel exports (imports) as a percentage of: Total merchandise exports, 1980
Algeria	18.9	1,940	7.0	8.0	57	144	97
Angola	7.6	. .	. .	. .	. .	*97*	*49*
Argentina	27.7	2,590	2.3	2.3	38	(8)	(10)
Bangladesh	88.5	130	3.9	9.5	13	*(14)*	*(34)*
Benin	3.5	290	3.3	3.7	10	*(5)*	*(39)*
Bolivia	5.6	570	4.8	4.3	29	*15*	*16*
Brazil	118.3	2,160	8.4	9.1	34	(42)	(52)
Burundi	4.1	210	3.4	8.4	16	*(9)*	*(14)*
Cameroon	8.4	730	5.6	8.6	20	15	17
Chile	11.1	2,290	1.4	−0.1	38	*(20)*	*(22)*
China	979.6	270	5.8	. .	48	. .	. .
Colombia	25.9	1,260	5.8	4.9	31	(10)	(12)
Congo, P.R.	1.6	880	4.2	13.0	47	*156*	*82*
Costa Rica	2.3	1,390	5.8	8.3	28	(15)	(23)
Dominican Rep.	5.4	1,190	6.6	8.3	28	(25)	(51)
Ecuador	8.4	1,100	9.1	13.8	38	. .	. .
Egypt	42.3	550	7.2	7.6	38	39	63
El Salvador	4.5	670	4.2	4.9	20	(16)	(21)
Ethiopia	31.1	130	2.5	−1.4	16	(20)	(35)
Gabon	0.7	3,700	5.7	. .	65	*270*	*78*
Ghana	11.5	390	−0.2	−1.6	12	*(13)*	*(14)*
Greece	9.6	4,160	4.6	5.0	31	(16)	(32)
Guatemala	7.3	1,080	5.8	7.7	. .	(23)	(24)
Haiti	5.0	280	3.5	7.7	. .	. .	. .
Honduras	3.7	560	4.2	5.0	25	(16)	(19)
Hong Kong	5.1	4310	9.7	7.6	27	(5)	(6)
India	675.0	230	3.6	4.7	25	*(33)*	*(43)*
Indonesia	146.3	450	7.8	11.5	43	129	64
Iran	38.8	. .	7.4	4.0	*54*	*175*	*97*
Iraq	13.1	. .	11.3	13.6	*73*	*259*	*99*
Ivory Coast	8.3	1,110	6.4	9.7	23	*(14)*	*(13)*
Jamaica	2.2	1,090	−1.1	−3.5	37	(36)	(44)
Kenya	16.6	390	6.4	9.0	22	(17)	(31)
Korea, Rep. of	38.2	1,490	9.5	15.4	41	(30)	(38)
Malawi	6.0	190	5.9	6.9	20	(15)	(24)
Malaysia	13.9	1,580	7.8	9.5	37	15	12
Mexico	69.4	1,980	6.4	7.2	37	*19*	*27*
Morocco	20.2	830	5.6	6.4	32	(21)	(36)
Mozambique	12.1	. .	−2.5	−5.3	17	*(2)*	*(4)*
Nepal	14.6	140	2.3	. .	*12*	(18)	(43)
Nicaragua	2.7	760	1.0	2.4	31	(19)	(40)
Niger	5.5	300	2.7	11.3	34	. .	. .
Nigeria	84.7	870	5.2	7.3	41	*149*	*94*
Pakistan	82.1	310	4.7	5.2	25	(24)	(48)
Panama	1.8	1,730	4.0	1.9	. .	(25)	(102)
Papua New Guinea	3.0	780	2.2	8.5	*30*	. .	. .
Paraguay	3.0	1,410	8.6	10.6	25	*(24)*	*(41)*
Peru	16.6	1,080	3.0	3.6	45	24	19
Philippines	48.3	710	6.4	8.7	37	(28)	(40)
Portugal	9.8	2,300	4.3	4.5	46	(21)	(43)
Rwanda	5.2	220	5.2	. .	22	. .	. .
Senegal	5.7	420	2.5	5.0	25	(17)	(36)
Sierra Leone	3.5	300	1.7	−3.8	22	. .	. .
Singapore	2.4	4,420	8.5	8.8	39	(8)	(10)
Somalia	4.3	260	3.9	−2.6	*11*	*(5)*	*(11)*
Sri Lanka	14.7	270	4.4	4.0	30	(16)	(32)
Sudan	18.7	360	4.0	3.1	14	(12)	(31)
Tanzania	18.5	270	4.5	2.9	16	(19)	(43)
Thailand	47.0	670	7.2	10.0	29	(30)	(44)
Trinidad and Tobago	1.2	5,010	4.9	4.0	57	81	64
Tunisia	6.4	1,260	7.5	9.5	37	13	20
Turkey	44.4	1,390	5.6	6.6	30	(48)	(125)
Uganda	12.6	200	−1.7	−9.5	4	. .	38
Uruguay	2.9	2,620	3.5	5.2	33	(29)	(45)
Venezuela	14.9	3,910	5.0	3.0	47	168	93
Yugoslavia	22.3	2,540	6.1	7.1	43	(22)	(37)
Zaire	28.9	200	−0.3	−0.9	29	*(6)*	*(5)*
Zambia	5.6	580	0.7	0.1	39	*(15)*	*(11)*
Zimbabwe	6.9	780	1.6	1.8	38	. .	. .

Note: For explanation of figures in *italics*, see Sources and Technical Notes.

2 Commercial Primary Energy Indicators

Country	Production: Thousand toe, 1980	Production: Average annual growth rate, 1970–80	Consumption: Thousand toe, 1980	Consumption: Average annual growth rate, 1970–80	Net trade (exports-imports): Thousand toe, 1980	Net trade (exports-imports): Average annual growth rate, 1970–80	Energy consumption per capita (toe per 1,000 people): 1970	Energy consumption per capita (toe per 1,000 people): 1980	Energy consumption per unit GDP (toe per million US dollars): 1970	Energy consumption per unit GDP (toe per million US dollars): 1980
Algeria	60,895	2.0	10,586	14.9	50,309	0.7	192.3	559.5	121.9	262.5
Angola	7,819	4.1	1,330	2.6	6,489	4.6	183.4	175.4	107.2	. .
Argentina	35,430	3.2	41,221	3.6	−5,791	−6.3	1,223.6	1,486.0	240.8	268.8
Bangladesh	1,314	. .	2,956	. .	−1,642	. .	. .	33.4	. .	265.3
Benin	22	. .	168	5.2	−147	−3.8	38.2	48.3	130.1	157.8
Bolivia	3,372	9.8	1,732	8.1	1,640	10.9	184.0	311.0	202.1	283.9
Brazil	43,170	8.1	89,627	9.0	−46,457	−9.7	398.7	757.4	350.0	360.5
Burundi	14	. .	45	6.1	−31	−4.8	7.5	10.9	36.9	50.6
Cameroon	3,129	26.3	892	4.9	2,238	25.7	81.8	105.6	152.7	135.2
Chile	5,450	0.9	8,681	0.6	−3,231	−0.5	876.2	781.8	382.9	316.1
China	438,490	7.5	416,200	5.4	22,290	80.7	302.3	424.9	. .	. .
Colombia	15,560	−0.3	17,277	4.9	−1,717	−15.4	502.1	667.3	560.5	515.6
Congo, P.R.	3,180	54.9	505	13.9	2,675	39.4	115.2	314.6	142.3	288.8
Costa Rica	545	8.3	1,299	7.1	−754	−6.3	379.3	570.0	235.8	268.0
Dominican Rep.	14	−4.4	1,931	6.7	−1,918	−6.5	248.2	355.6	280.4	275.2
Ecuador	11,030	41.9	3,977	11.7	7,053	23.8	217.8	476.1	269.6	349.8
Egypt	33,880	6.7	17,296	9.3	16,584	4.2	218.9	409.0	573.5	714.5
El Salvador	340	10.6	1,114	7.6	−744	−6.1	158.0	245.4	217.8	328.9
Ethiopia	105	4.4	523	−1.0	−418	1.6	22.8	16.8	190.5	127.9
Gabon	8,840	5.0	1,470	13.7	7,370	3.9	700.0	2,237.4	166.9	377.4
Ghana	1,250	5.2	2,119	3.0	−870	−0.9	182.5	184.3	117.1	154.5
Greece	4,145	9.0	17,193	7.3	−13,048	−6.8	964.5	1,791.1	334.1	428.3
Guatemala	153	5.9	1,537	5.9	−1,384	−5.6	163.9	211.6	190.0	195.7
Haiti	60	. .	301	9.1	−241	−6.5	29.8	60.1	126.9	207.6
Honduras	250	17.2	741	4.5	−491	−1.7	181.4	200.8	286.7	292.0
Hong Kong	—	. .	6,555	5.7	−6,555	−5.5	954.2	1,293.4	420.1	*293.7*
India	76,640	4.1	97,302	4.6	−20,662	−5.2	113.5	144.2	534.8	611.1
Indonesia	93,630	7.8	26,735	8.8	66,895	8.2	98.7	182.7	339.2	368.8
Iran	80,653	−8.8	32,298	1.9	48,355	−12.1	940.5	831.8	. .	. .
Iraq	132,710	5.6	10,971	9.4	121,739	5.2	478.8	839.3	314.1	293.4
Ivory Coast	353	17.9	1,407	6.3	−1,054	−3.1	152.2	170.3	132.9	134.1
Jamaica	31	−0.3	2,150	1.7	−2,120	−0.9	970.0	989.9	. .	. .
Kenya	250	11.0	2,382	4.1	−2,132	−3.8	141.0	143.1	464.2	*340.7*
Korea, Rep. of	9,880	3.9	41,054	9.9	−31,174	−12.1	501.9	1,074.8	624.8	704.8
Malawi	85	9.6	269	5.7	−184	−6.6	34.1	44.6	183.0	176.0
Malaysia	15,190	28.4	8,406	3.9	6,784	9.7	536.0	606.0	514.6	*353.0*
Mexico	131,410	12.7	80,368	7.1	51,042	46.9	801.0	1,158.2	409.8	431.3
Morocco	1,050	3.6	5,105	7.2	−4,055	−8.1	169.5	252.9	236.7	286.4
Mozambique	460	3.9	1,129	0.6	−669	1.2	131.1	93.4	346.5	402.6
Nepal	50	13.6	144	2.2	−94	0.1	10.2	9.8	69.5	74.0
Nicaragua	120	3.6	731	3.5	−611	−3.1	270.2	273.6	259.5	344.3
Niger	20	. .	205	12.0	−185	−9.8	16.5	37.1	46.1	108.2
Nigeria	104,220	6.7	9,841	15.6	94,379	6.4	34.8	116.1	48.3	122.6
Pakistan	8,620	7.5	12,627	3.8	−4,007	−0.3	144.0	153.9	570.8	532.5
Panama	200	25.3	2,047	−3.2	−1,847	4.2	1,925.6	1,115.5	. .	603.7
Papua New Guinea	100	11.1	719	10.0	−619	−9.0	115.7	239.1	137.8	278.4
Paraguay	250	20.1	616	8.8	−366	−4.0	115.2	206.6	136.1	138.5
Peru	12,280	9.2	9,216	4.0	3,064	14.7	463.5	554.8	440.2	479.0
Philippines	2,140	14.2	12,615	4.1	−10,475	−2.2	229.0	261.2	433.0	356.2
Portugal	2,640	4.4	12,217	6.2	−9,577	−6.4	776.4	1,252.8	441.4	507.4
Rwanda	48	8.1	101	9.4	−52	−9.6	10.7	19.5	56.8	88.0
Senegal	—	. .	1,425	−1.0	−1,425	1.1	357.6	249.9	671.0	500.4
Sierra Leone	3	. .	396	−0.5	−393	0.6	155.3	114.0	464.2	362.9
Singapore	—	. .	14,189	8.7	−14,188	−5.2	2,958.6	5,875.4	1,338.5	*1,292.2*
Somalia	—	. .	249	12.3	−249	−11.0	25.1	58.3	101.1	224.5
Sri Lanka	375	7.0	2,040	0.1	−1,665	1.1	161.5	138.4	769.0	507.0
Sudan	150	19.2	1,297	−2.2	−1,147	3.5	115.2	69.4	326.1	191.9
Tanzania	202	9.4	875	2.8	−675	−1.5	51.5	47.2	223.6	177.5
Thailand	724	2.4	11,935	8.2	−11,211	−7.8	148.4	254.2	316.1	356.8
Trinidad and Tobago	13,260	4.0	5,872	1.2	7,388	10.8	5,058.4	5,027.4	1,297.7	*909.5*
Tunisia	6,130	3.9	2,852	8.4	3,278	1.8	248.1	477.8	311.6	327.7
Turkey	11,305	2.9	23,793	−6.7	−12,488	−11.0	351.9	535.4	359.6	418.0
Uganda	100	−6.7	318	−5.7	−218	7.1	58.0	25.2	. .	. .
Uruguay	500	4.4	2,319	0.8	−1,819	−0.1	760.6	797.5	297.8	235.1
Venezuela	121,875	−5.1	31,202	1.1	90,673	−6.5	2,618.9	2,089.9	705.7	*519.8*
Yugoslavia	23,580	4.1	36,900	5.4	−13,320	−7.7	1,071.1	1,651.5	556.9	532.0
Zaire	2,073	8.7	2,117	1.9	−44	32.2	80.7	73.3	306.3	355.9
Zambia	1,950	4.1	2,848	3.5	−898	−6.7	476.4	504.3	576.2	752.0
Zimbabwe	3,210	−1.7	3,688	−0.8	−478	−13.9	752.3	534.8	956.2	656.9

Note: For explanation of figures in *italics*, see Sources and Technical Notes.

3 Commercial Primary Energy Production

	Commercial primary energy production, 1980 (thousand toe)				
Country	*Total*	*Liquid fuels*	*Solid fuels*	*Natural gas*	*Primary electricity*
Algeria	60,895	50,790	5	10,000	100
Angola	7,819	7,470	—	77	272
Argentina	35,430	24,400	280	7,000	3,750
Bangladesh	1,314	—	—	1,164	150
Benin	22	—	—	—	22
Bolivia	3,372	1,100	—	2,000	272
Brazil	43,170	8,960	2,210	1,000	31,000
Burundi	14	—	5	—	9
Cameroon	3,129	2,790	—	2	338
Chile	5,450	1,590	690	1,500	1,670
China	438,490	105,320	305,670	13,000	14,500
Colombia	15,560	6,220	3,040	2,700	3,600
Congo, P.R.	3,180	3,140	—	20	20
Costa Rica	545	—	—	—	545
Dominican Rep.	14	—	—	—	14
Ecuador	11,030	10,710	—	70	250
Egypt	33,880	29,630	—	2,000	2,250
El Salvador	340	—	—	—	340
Ethiopia	105	—	—	—	105
Gabon	8,840	8,710	—	130	—
Ghana	1,250	100	—	—	1,150
Greece	4,145	3	3,040	2	1,100
Guatemala	153	80	—	—	73
Haiti	60	—	—	—	60
Honduras	250	—	—	—	250
Hong Kong	..	..	..	..	..
India	76,640	8,960	53,680	1,000	13,000
Indonesia	93,630	78,680	200	14,000	750
Iran	80,653	72,283	620	7,000	750
Iraq	132,710	131,460	—	1,000	250
Ivory Coast	353	100	—	3	250
Jamaica	31	—	—	—	31
Kenya	250	—	—	—	250
Korea, Rep. of	9,880	—	8,630	—	1,250
Malawi	85	—	—	—	85
Malaysia	15,190	13,940	—	1,000	250
Mexico	131,410	96,600	3,310	25,000	6,500
Morocco	1,050	10	480	60	500
Mozambique	460	—	280	—	180
Nepal	50	—	—	—	50
Nicaragua	120	—	—	—	120
Niger	20	—	—	—	20
Nigeria	104,220	102,580	140	1,000	500
Pakistan	8,620	500	620	5,000	2,500
Panama	200	—	—	—	200
Papua New Guinea	100	—	—	—	100
Paraguay	250	—	—	—	250
Peru	12,280	9,460	70	1,000	1,750
Philippines	2,140	500	140	—	1,500
Portugal	2,640	—	140	—	2,500
Rwanda	48	—	—	—	48
Senegal	..	..	..	..	..
Sierra Leone	3	—	—	—	3
Singapore	..	..	..	..	..
Somalia	..	..	..	..	..
Sri Lanka	375	—	—	—	375
Sudan	150	—	—	—	150
Tanzania	202	—	—	2	200
Thailand	724	10	210	4	500
Trinidad and Tobago	13,260	10,760	—	2,500	—
Tunisia	6,130	5,730	—	400	—
Turkey	11,305	2,240	5,730	85	3,250
Uganda	100	—	—	—	100
Uruguay	500	—	—	—	500
Venezuela	121,875	108,060	65	10,000	3,750
Yugoslavia	23,580	4,230	10,350	2,000	7,000
Zaire	2,073	1,000	70	3	1,000
Zambia	1,950	—	350	—	1,600
Zimbabwe	3,210	—	2,210	—	1,000

Distribution of production, 1980 (percent)				*Average annual growth rate, 1970–80*				
Liquid fuels	*Solid fuels*	*Natural gas*	*Primary electricity*	*Liquid fuels*	*Solid fuels*	*Natural gas*	*Primary electricity*	*Total*
83	—	17	—	0.5	−5.7	20.9	−4.1	2.0
96	—	1	3	4.0	—	7.0	7.2	4.1
69	1	20	10	1.9	−2.4	3.6	24.8	3.2
—	—	89	11	. .	. .	. .	. .	. .
—	—	—	100	—	—	—	. .	—
33	—	59	8	−0.2	—	52.2	4.9	9.8
21	5	2	72	1.1	6.7	29.2	11.5	8.1
—	36	—	64	—	. .	—	. .	—
89	—	—	11	. .	—	. .	1.1	26.3
29	13	27	31	−1.0	−3.1	2.8	4.0	0.9
24	70	3	3	13.1	5.8	17.5	11.0	7.5
40	20	17	23	−6.1	6.9	7.6	8.3	−0.3
98	—	1	1	66.7	—	8.3	5.2	54.9
—	—	—	100	—	—	—	8.3	8.3
—	—	—	100	—	—	—	−4.4	−4.4
97	—	1	2	48.0	—	15.9	9.0	41.9
87	—	6	7	6.1	—	38.3	6.2	6.7
—	—	—	100	—	—	—	10.6	10.6
—	—	—	100	—	—	—	4.4	4.4
99	—	1	—	4.9	—	20.6	—	5.0
8	—	—	92	58.5	—	—	4.3	5.2
—	73	—	27	. .	11.2	. .	4.8	9.0
52	—	—	48	. .	—	—	−1.6	5.9
—	—	—	100	—	—	—	. .	—
—	—	—	100	—	—	—	17.2	17.2
—	—	—	—	—	—	—	—	—
12	70	1	17	2.8	3.8	8.4	6.0	4.1
84	—	15	1	6.3	5.4	29.0	8.7	7.8
90	1	8	1	−9.3	5.5	−4.1	5.5	−8.8
99	—	1	—	5.6	—	3.4	. .	5.6
28	—	1	71	. .	—	. .	13.9	17.9
—	—	—	100	—	—	—	−0.3	−0.3
—	—	—	100	—	—	—	11.0	11.0
—	87	—	13	—	3.0	—	14.6	3.9
—	—	—	100	—	—	—	9.6	9.6
92	—	6	2	32.1	—	30.7	−2.3	28.4
73	3	19	5	15.1	8.6	9.0	5.1	12.7
1	46	6	47	−13.8	4.9	3.4	3.5	3.6
—	61	—	39	—	1.5	—	9.6	3.9
—	—	—	100	—	—	—	13.6	13.6
—	—	—	100	—	—	—	3.6	3.6
—	—	—	100	—	—	—	. .	—
98	—	1	1	6.6	13.1	25.6	3.4	6.7
6	7	58	29	0.9	0.1	8.3	11.2	7.5
—	—	—	100	—	—	—	25.3	25.3
—	—	—	100	—	—	—	11.1	11.1
—	—	—	100	—	—	—	20.1	20.1
77	1	8	14	10.1	−4.2	10.3	5.7	9.2
23	7	—	70	. .	22.1	—	10.6	14.2
—	5	—	95	—	−2.8	—	5.0	4.4
—	—	—	100	—	—	. .	8.6	8.1
. .	. .	. .	. .	. .	. .	. .	. .	. .
—	—	—	100	—	—	. .	. .	—
. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .	. .
—	—	—	100	—	—	—	7.0	7.0
—	—	—	100	—	—	—	19.2	19.2
—	—	1	99	—	. .	. .	9.6	9.4
1	29	1	69	—	8.7	. .	0.6	2.4
81	—	19	—	4.0	—	3.9	—	4.0
93	—	7	—	3.3	—	55.0	. .	3.9
20	50	1	29	−4.5	3.3	. .	15.1	2.9
—	—	—	100	—	—	—	−6.7	−6.7
—	—	—	100	—	—	—	4.4	4.4
89	—	8	3	−5.8	8.8	1.1	13.3	−5.1
18	44	8	30	4.0	2.4	8.0	6.1	4.1
48	4	—	48	. .	—	. .	1.9	8.7
—	18	—	82	—	−0.3	—	5.4	4.1
—	69	—	31	—	−0.9	—	−3.1	−1.4

4 Commercial Primary Energy Consumption

Country	Total	Liquid fuels	Solid fuels	Natural gas	Primary electricity
	Commercial primary energy consumption, 1980 (thousand toe)				
Algeria	10,586	6,836	150	3,500	100
Angola	1,330	981	..	77	272
Argentina	41,221	27,784	800	8,887	3,750
Bangladesh	2,956	1,520	122	1,164	150
Benin	168	146	..	..	22
Bolivia	1,732	1,347	..	113	272
Brazil	89,627	51,827	5,800	1,000	31,000
Burundi	45	31	5	..	9
Cameroon	892	554	—	..	338
Chile	8,681	4,311	1,200	1,500	1,670
China	416,200	87,700	301,000	13,000	14,500
Colombia	17,277	7,877	3,100	2,700	3,600
Congo, P.R.	505	465	..	20	20
Costa Rica	1,299	754	..	..	545
Dominican Rep.	1,931	1,917	1	..	14
Ecuador	3,977	3,657	..	70	250
Egypt	17,296	12,046	1,000	2,000	2,250
El Salvador	1,114	774	..	..	340
Ethiopia	523	418	—	..	105
Gabon	1,470	1,340	..	130	—
Ghana	2,119	963	6	..	1,150
Greece	17,193	12,893	3,200	..	1,100
Guatemala	1,537	1,464	..	..	73
Haiti	301	241	—	..	60
Honduras	741	491	—	..	250
Hong Kong	6,555	6,547	8	..	—
India	97,302	29,600	53,702	1,000	13,000
Indonesia	26,735	21,185	200	4,600	750
Iran	32,298	24,248	600	6,700	750
Iraq	10,971	9,721	..	1,000	250
Ivory Coast	1,407	1,154	..	3	250
Jamaica	2,150	2,118	1	..	31
Kenya	2,382	2,088	44	..	250
Korea, Rep. of	41,054	26,604	13,200	—	1,250
Malawi	269	155	29	..	85
Malaysia	8,406	7,116	40	1,000	250
Mexico	80,368	47,668	3,900	22,300	6,500
Morocco	5,105	4,010	535	60	500
Mozambique	1,129	779	170	..	180
Nepal	144	88	6	..	50
Nicaragua	731	611	..	..	120
Niger	205	185	—	—	20
Nigeria	9,841	8,141	200	1,000	500
Pakistan	12,627	4,527	600	5,000	2,500
Panama	2,047	1,847	—	..	200
Papua New Guinea	719	619	—	..	100
Paraguay	616	366	..	..	250
Peru	9,216	6,316	150	1,000	1,750
Philippines	12,615	10,975	140	..	1,500
Portugal	12,217	9,187	530	..	2,500
Rwanda	101	52	..	1	48
Senegal	1,425	1,425	..	..	—
Sierra Leone	396	393	..	..	3
Singapore	14,189	14,188	1	..	—
Somalia	249	249	..	..	..
Sri Lanka	2,040	1,660	5	..	375
Sudan	1,297	1,147	—	..	150
Tanzania	875	672	3	—	200
Thailand	11,935	11,091	340	4	500
Trinidad and Tobago	5,872	3,372	..	2,500	—
Tunisia	2,852	2,452	..	400	—
Turkey	23,793	15,458	5,000	85	3,250
Uganda	318	218	..	..	100
Uruguay	2,319	1,808	11	..	500
Venezuela	31,202	17,192	260	10,000	3,750
Yugoslavia	36,900	14,100	14,000	1,800	7,000
Zaire	2,117	936	178	3	1,000
Zambia	2,848	877	371	..	1,600
Zimbabwe	3,688	544	2,144	..	1,000

Distribution of consumption, 1980 (percent)				*Average annual growth rate, 1970–80*				
Liquid fuels	*Solid fuels*	*Natural gas*	*Primary electricity*	*Liquid fuels*	*Solid fuels*	*Natural gas*	*Primary electricity*	*Total*
65	1	33	1	12.1	−5.1	49.0	−4.1	14.9
74	—	6	20	1.6	. .	7.0	7.2	2.6
67	2	22	9	2.0	−1.4	6.1	24.9	3.6
52	4	39	5	. .	. .	. .	. .	. .
87	—	—	13	3.8	. .	. .	. .	5.2
78	—	6	16	8.5	. .	14.2	4.9	8.1
58	6	1	35	7.6	8.4	29.2	11.5	9.0
69	11	—	20	5.0	. .	. .	4.1	6.1
62	—	—	38	8.2	. .	. .	1.1	4.9
50	14	17	19	−0.9	−0.2	2.9	4.0	0.6
21	72	3	4	13.7	3.6	14.4	7.4	5.4
46	18	15	21	2.4	7.1	7.6	8.3	4.9
92	—	4	4	14.8	. .	8.3	5.2	13.9
58	—	—	42	6.3	. .	. .	8.3	7.1
99	—	—	1	6.9	—	. .	−4.4	6.7
92	—	2	6	11.9	. .	15.9	9.0	11.7
70	6	11	13	8.3	12.1	38.3	6.2	9.3
69	—	—	31	6.5	. .	. .	10.6	7.6
80	—	—	20	−2.0	—	. .	4.4	−1.0
91	—	9	—	13.3	. .	20.6	—	13.7
45	1	—	54	1.9	−12.2	. .	4.3	3.0
75	19	—	6	7.2	9.0	. .	4.7	7.3
95	—	—	5	6.5	. .	. .	−1.6	5.9
80	—	—	20	6.7	. .	. .	. .	9.1
66	—	—	34	1.4	. .	. .	17.2	4.5
100	—	—	—	5.8	9.2	. .	. .	5.7
30	55	1	14	4.5	4.3	8.4	6.0	4.6
79	1	17	4	7.9	6.1	15.4	8.7	8.8
75	2	21	2	4.2	5.1	−3.7	5.5	1.9
89	—	9	2	10.0	. .	3.4	. .	9.4
82	—	—	18	5.2	. .	. .	13.9	6.3
99	—	—	1	1.8	—	. .	−0.3	1.7
88	2	—	10	4.3	−2.6	. .	5.0	4.1
65	32	—	3	10.6	8.2	. .	14.6	9.9
58	11	—	31	5.2	0.4	. .	9.6	5.7
84	1	12	3	3.0	9.6	24.5	−2.3	3.9
59	5	28	8	6.8	8.2	8.5	5.0	7.1
79	10	1	10	8.1	5.5	3.4	3.5	7.2
69	15	—	16	2.2	−8.2	. .	16.8	0.6
61	4	—	35	−0.8	−1.5	. .	13.6	2.2
84	—	—	16	3.5	. .	. .	3.6	3.5
90	—	—	10	10.9	. .	. .	. .	12.0
83	2	10	5	16.3	16.1	25.6	3.4	15.6
36	5	39	20	−0.1	−5.1	8.3	11.2	3.8
90	—	—	10	−4.1	. .	. .	. .	−3.2
86	—	—	14	9.8	. .	. .	11.1	10.0
59	—	—	41	5.0	. .	. .	20.1	8.8
68	2	11	19	3.1	−3.3	10.3	5.7	4.0
87	1	—	12	3.4	16.7	. .	10.6	4.1
75	4	—	21	7.8	−4.2	. .	5.0	6.2
51	—	1	48	10.6	. .	—	9.1	9.4
100	—	—	—	−1.0	. .	. .	. .	−1.0
99	—	—	1	−0.6	. .	. .	. .	−0.5
100	—	—	—	8.7	−6.7	. .	. .	8.7
100	—	—	—	12.3	. .	. .	. .	12.3
81	1	—	18	−0.9	−10.4	. .	7.0	0.1
88	—	—	12	−3.2	. .	. .	19.2	−2.2
77	—	—	23	1.4	—	. .	9.6	2.8
93	3	—	4	8.6	13.4	. .	0.9	8.2
57	—	43	—	−0.3	. .	3.9	. .	1.2
86	—	14	—	7.8	. .	55.0	. .	8.4
65	21	—	14	7.6	1.7	. .	15.1	6.7
69	—	—	31	−6.6	. .	. .	−3.0	−5.7
78	1	—	21	0.1	−5.8	. .	4.1	0.8
55	1	32	12	−0.3	0.7	1.1	13.3	1.1
38	38	5	19	6.2	4.2	6.9	6.0	5.4
44	8	1	47	2.1	−1.4	. .	2.5	1.9
31	13	—	56	7.9	−5.2	. .	5.0	3.5
15	58	—	27	1.1	—	. .	−3.1	−0.8

5 Commercial Primary Energy Trade

Country	Imports (thousand toe)				Exports (thousand toe)			
	Liquid fuels increase (decrease), 1970–80	*Liquid fuels, 1980*	*Solid fuels, 1980*	*Natural gas, 1980*	*Liquid fuels increase (decrease), 1970–80*	*Liquid fuels, 1980*	*Solid fuels, 1980*	*Natural gas, 1980*
Algeria	1,228	1,296	145	. .	(1,560)	45,249	. .	6,500
Angola	(75)	184	. .	. .	2,286	6,672	. .	. .
Argentina	1,210	3,728	520	1,887	250	344	. .	. .
Bangladesh	. .	1,530	122	. .	. .	9	. .	. .
Benin	41	165	. .	. .	(7)	18	. .	. .
Bolivia	433	444	. .	. .	(397)	196	. .	1,887
Brazil	27,443	45,292	3,590	. .	1,396	2,425	. .	. .
Burundi	12	31	. .	. .	. .	. .	—	. .
Cameroon	302	554	. .	. .	. .	2,790	. .	2
Chile	(152)	2,754	511	511	19	33	1	. .
China	(328)	98	. .	. .	17,713	17,718	4,670	. .
Colombia	2,992	2,994	60	. .	(4,157)	1,337	. .	. .
Congo, P.R.	(114)	3	. .	. .	2,661	2,678	. .	. .
Costa Rica	312	754	. .	. .	. .	. .	. .	. .
Dominican Rep.	937	1,917	1	. .	. .	. .	. .	. .
Ecuador	(765)	229	. .	. .	7,238	7,282	. .	. .
Egypt	(3,448)	284	1,001	. .	3,185	17,869	1	. .
El Salvador	377	788	. .	. .	. .	14	. .	. .
Ethiopia	18	644	. .	. .	90	226	. .	. .
Gabon	47	51	. .	. .	2,381	7,421	. .	. .
Ghana	274	1,157	5	. .	204	293	. .	. .
Greece	13,256	19,869	160	. .	6,821	6,979	. .	2
Guatemala	604	1,384	. .	. .	. .	. .	. .	. .
Haiti	118	241	. .	. .	. .	. .	. .	. .
Honduras	(248)	515	. .	. .	(325)	24	. .	. .
Hong Kong	2,960	6,715	8	. .	118	168	. .	. .
India	8,267	20,640	22	. .	. .	. .	. .	. .
Indonesia	2,352	2,691	22	. .	29,396	60,186	22	9,400
Iran	. .	. .	. .	. .	(127,810)	48,035	20	300
Iraq	(33)	1	. .	. .	48,366	121,740	. .	. .
Ivory Coast	673	1,520	. .	—	385	465	. .	. .
Jamaica	76	2,164	1	. .	(105)	45	. .	. .
Kenya	434	2,822	44	. .	(212)	734	. .	. .
Korea, Rep. of	17,711	26,635	4,572	. .	(226)	31	2	. .
Malawi	49	155	29	. .	. .	. .	. .	. .
Malaysia	(6,630)	3,685	40	. .	4,644	10,508	. .	. .
Mexico	(1,171)	697	590	60	47,069	49,629	—	2,760
Morocco	2,252	4,000	74	. .	. .	. .	19	. .
Mozambique	(122)	786	141	. .	(273)	7	251	. .
Nepal	(7)	88	6	. .	. .	. .	. .	. .
Nicaragua	161	612	. .	. .	(3)	1	. .	. .
Niger	119	185	. .	. .	. .	. .	. .	. .
Nigeria	(342)	342	63	. .	43,551	94,781	3	. .
Pakistan	(58)	4,429	. .	. .	39	402	20	. .
Panama	(1,399)	2,300	. .	. .	(425)	453	. .	. .
Papua New Guinea	378	619	. .	. .	. .	. .	. .	. .
Paraguay	142	366	. .	. .	. .	. .	. .	. .
Peru	(1,071)	204	80	. .	3,113	3,348	. .	. .
Philippines	1,444	10,576	. .	. .	(674)	101	. .	. .
Portugal	4,590	9,513	390	. .	(142)	326	. .	. .
Rwanda	33	52	. .	. .	. .	. .	. .	. .
Senegal	(23)	1,600	. .	. .	144	175	. .	. .
Sierra Leone	(27)	394	. .	. .	(2)	1	. .	. .
Singapore	12,031	32,258	6	. .	6,120	18,070	5	. .
Somalia	171	249	. .	. .	. .	. .	. .	. .
Sri Lanka	(405)	1,720	5	. .	(149)	60	. .	. .
Sudan	(469)	1,147	. .	. .	. .	. .	. .	. .
Tanzania	(434)	721	3	. .	(523)	49	. .	. .
Thailand	6,066	11,104	130	—	(11)	23	. .	. .
Trinidad and Tobago	(8,272)	7,638	. .	. .	(3,524)	15,025	. .	. .
Turkey	9,138	13,257	. .	—	2,375	5,609	. .	. .
Tunisia	1,830	2,331	. .	. .	(1)	38	730	. .
Uganda	(215)	221	. .	. .	—	3	. .	. .
Uruguay	14	1,808	11	. .	. .	. .	. .	. .
Venezuela	(1)	—	195	. .	(86,454)	90,868	. .	. .
Yugoslavia	5,194	10,610	3,924	. .	181	740	274	200
Zaire	(54)	827	108	. .	772	890	. .	. .
Zambia	565	974	22	. .	. .	98	1	. .
Zimbabwe	57	544	. .	. .	. .	. .	66	. .

Note: Figures in parentheses indicate decrease in imports or exports.

6 Energy Reserves and Potential

Country	Proven reserves: Crude oil (million barrels)	Proven reserves: Natural gas (billion cubic feet)	Proven reserves: Coal (million tce)	Hydro potential (megawatts)	Geothermal potential
Algeria	9,440	111,250	. .	287	. .
Angola	1,635	1,470	. .	23,000	. .
Argentina	2,590	25,200	290	40,000	. .
Bangladesh	. .	7,000	519	800	. .
Benin	. .	. .	. .	500	. .
Bolivia	180	5,700	. .	18,000	. .
Brazil	1,750	2,330	8,098	213,140	. .
Burundi	. .	. .	. .	800	. .
Cameroon	530	4,450	. .	23,000	. .
Chile	760	2,515	162	18,772	. .
China	19,485	29,800	. .	378,532	*
Colombia	536	4,580	3,000	94,358	. .
Congo, P.R.	1,550	2,700	. .	11,000	. .
Costa Rica	. .	. .	. .	9,071	*
Dominican Rep.	. .	. .	. .	1,900	. .
Ecuador	1,400	4,100	. .	22,733	. .
Egypt	3,325	7,180	. .	2,660	. .
El Salvador	. .	. .	. .	1,377	*
Ethiopia	. .	. .	. .	12,000	*
Gabon	460	485	. .	18,000	. .
Ghana	5	. .	. .	2,000	. .
Greece	60	3,500	. .	. .	. .
Guatemala	50	35	. .	5,426	*
Haiti	. .	. .	. .	152	. .
Honduras	. .	. .	. .	2,800	*
Hong Kong	. .	. .	. .	. .	. .
India	3,416	14,508	33,700	100,000	. .
Indonesia	9,550	29,600	1,430	32,000	*
Iran	55,308	482,600	193	. .	. .
Iraq	41,000	28,800	. .	. .	. .
Ivory Coast	111	3,040	. .	3,000	. .
Jamaica	. .	. .	. .	100	. .
Kenya	. .	. .	. .	6,000	*
Korea, Rep. of	. .	. .	386	2,000	*
Malawi	. .	. .	. .	900	. .
Malaysia	3,325	34,000	. .	25,800	. .
Mexico	48,300	75,850	875	25,250	*
Morocco	. .	136	. .	2,453	. .
Mozambique	. .	. .	80	15,000	. .
Nepal	. .	. .	. .	18,250	. .
Nicaragua	. .	. .	. .	4,106	*
Niger	. .	. .	. .	235	. .
Nigeria	16,750	32,400	90	12,400	. .
Pakistan	196	18,540	. .	19,600	. .
Panama	. .	. .	. .	3,031	. .
Papua New Guinea	. .	. .	. .	29,000	. .
Paraguay	. .	. .	. .	10,965	. .
Peru	835	1,201	105	60,000	. .
Philippines	36	16	. .	10,048	*
Portugal	. .	. .	. .	6,000	. .
Rwanda	. .	. .	. .	600	*
Senegal	. .	. .	. .	500	. .
Sierra Leone	. .	. .	. .	1,300	. .
Singapore	. .	. .	. .	. .	. .
Somalia	. .	. .	. .	50	. .
Sri Lanka	. .	. .	. .	2,500	. .
Sudan	400	. .	. .	2,700	. .
Tanzania	. .	200	. .	9,500	*
Thailand	103	11,000	. .	20,148	. .
Trinidad and Tobago	580	11,000	. .	. .	. .
Tunisia	1,860	4,300	. .	65	. .
Turkey	280	545	793	32,000	*
Uganda	. .	. .	. .	1,200	. .
Uruguay	. .	. .	. .	2,248	. .
Venezuela	21,500	54,079	978	25,000	. .
Yugoslavia	300	2,472	8,465	17,000	. .
Zaire	139	48	. .	120,000	. .
Zambia	. .	. .	5	12,000	. .
Zimbabwe	. .	. .	. .	3,800	. .

Note: Asterisk indicates countries where geothermal potential has been identified.

7 Installed Power Capacity

Country	Liquid fuels	Solid fuels	Natural gas	Hydro	Geothermal	Nuclear	Total
	Classification by source, 1980 (megawatts)						
Algeria	58	—	1,643	287	—	—	1,988
Angola	155	—	—	553	—	—	708
Argentina	4,000	300	2,100	4,533	—	357	11,290
Bangladesh	257	—	495	80	—	—	832
Benin	17	—	—	—	—	—	17
Bolivia	115	—	98	287	—	—	500
Brazil	3,525	943	—	27,267	—	—	31,735
Burundi	9	—	—	—	—	—	9
Cameroon	95	—	—	263	—	—	358
Chile	598	659	213	1,471	—	—	2,941
China	10,762	34,602	187	20,318	—	—	65,869
Colombia	138	371	865	2,908	—	—	4,282
Congo, P.R.	28	—	—	90	—	—	118
Costa Rica	189	—	—	456	—	—	645
Dominican Rep.	874	21	—	172	—	—	1,067
Ecuador	898	—	60	225	—	—	1,183
Egypt	1,323	—	947	1,645	—	—	3,915
El Salvador	70	—	65	271	95	—	501
Ethiopia	21	—	—	216	—	—	237
Gabon	102	—	—	137	—	—	239
Ghana	84	—	—	792	—	—	876
Greece	2,035	2,800	—	1,415	—	—	6,250
Guatemala	344	—	—	103	—	—	447
Haiti	91	—	—	44	—	—	135
Honduras	91	—	—	122	—	—	213
Hong Kong	3,227	—	—	—	—	—	3,227
India	2,733	16,620	1,000	11,794	—	860	33,007
Indonesia	4,800	—	—	748	—	—	5,548
Iran	2,450	—	2,000	850	—	—	5,300
Iraq	916	—	700	84	—	—	1,700
Ivory Coast	268	—	—	614	—	—	882
Jamaica	558	101	—	21	—	—	680
Kenya	191	—	—	336	—	—	527
Korea, Rep. of	6,897	750	—	1,157	—	587	9,391
Malawi	30	—	—	101	—	—	131
Malaysia	1,938	—	115	642	—	—	2,695
Mexico	9,111	—	2,009	6,491	150	—	17,761
Morocco	618	165	—	613	—	—	1,396
Mozambique	250	—	—	2,258	—	—	2,508
Nepal	34	—	—	52	—	—	86
Nicaragua	248	—	15	103	—	—	366
Niger	47	—	—	—	—	—	47
Nigeria	163	30	1,348	760	—	—	2,301
Pakistan	25	25	1,598	1,847	—	137	3,632
Panama	456	—	—	297	—	—	753
Papua New Guinea	230	—	—	99	—	—	329
Paraguay	78	—	—	194	—	—	272
Peru	1,111	—	142	1,863	—	—	3,116
Philippines	3,026	61	—	947	443	—	4,477
Portugal	1,483	150	—	2,268	—	—	3,901
Rwanda	11	—	—	12	—	—	23
Senegal	196	—	—	—	—	—	196
Sierra Leone	96	—	—	2	—	—	98
Singapore	1,900	—	—	—	—	—	1,900
Somalia	90	—	—	—	—	—	90
Sri Lanka	86	—	—	313	—	—	399
Sudan	135	—	—	155	—	—	290
Tanzania	127	—	—	243	—	—	370
Thailand	2,226	210	165	1,270	—	—	3,871
Trinidad and Tobago	—	—	662	—	—	—	662
Tunisia	702	—	180	29	—	—	911
Turkey	1,488	1,500	—	2,131	—	—	5,119
Uganda	4	—	—	150	—	—	154
Uruguay	448	—	—	371	—	—	819
Venezuela	3,308	—	2,560	2,680	—	—	8,548
Yugoslavia	3,298	4,500	—	6,245	—	—	14,043
Zaire	67	—	—	1,077	—	—	1,144
Zambia	89	—	—	1,641	—	—	1,730
Zimbabwe	—	418	—	633	—	—	1,051

8 Installed Capacity for Electricity Generation

Country	Percentage of total generation capacity, 1980				Percentage of thermal generation capacity, 1980			
	Hydro	*Geothermal*	*Nuclear*	*Thermal*	*Steam*	*Gas turbine*	*Combined cycle*	*Diesel*
Algeria	14	—	—	86	65	35	—	—
Angola	78	—	—	22	—	—	—	100
Argentina	40	—	3	57	64	24	—	12
Bangladesh	10	—	—	90	57	38	—	5
Benin	—	—	—	100	—	—	—	100
Bolivia	57	—	—	43	—	60	40	—
Brazil	86	—	—	14	67	—	—	*33**
Burundi	7	—	—	93	—	—	—	100
Cameroon	73	—	—	27	—	—	—	100
Chile	50	—	—	50	75	12	—	13
China	31	—	—	69	*75**	—	—	25
Colombia	68	—	—	32	30	63	—	7
Congo, P.R.	76	—	—	24	—	—	—	100
Costa Rica	71	—	—	29	6	—	—	94
Dominican Rep.	16	—	—	84	64	33	—	3
Ecuador	19	—	—	81	—	—	—	100
Egypt	42	—	—	58	74	26	—	—
El Salvador	54	19	—	27	50	50	—	—
Ethiopia	91	—	—	9	29	—	—	71
Gabon	57	—	—	43	—	—	—	100
Ghana	90	—	—	10	—	—	—	100
Greece	23	—	—	77	. .	. .	. .	. .
Guatemala	23	—	—	77	51	39	—	10
Haiti	33	—	—	67	—	—	—	*100*
Honduras	57	—	—	43	—	100	—	—
Hong Kong	—	—	—	100	. .	. .	. .	. .
India	36	—	2	62	*88*	—	—	*12**
Indonesia	13	—	—	87	35	42	—	23
Iran	16	—	—	84	. .	. .	. .	. .
Iraq	5	—	—	95	. .	. .	. .	. .
Ivory Coast	70	—	—	30	80	4	—	16
Jamaica	3	—	—	97	100	—	—	—
Kenya	64	—	—	36	65	18	—	17
Korea, Rep. of	12	—	6	82	84	16	—	—
Malawi	77	—	—	23	—	65	—	35
Malaysia	24	—	—	76	73	6	—	21
Mexico	37	1	—	62	78	14	8	—
Morocco	44	—	—	56	80	17	—	3
Mozambique	90	—	—	10	—	—	—	100
Nepal	60	—	—	40	27	—	—	73
Nicaragua	28	—	—	72	87	13	—	—
Niger	—	—	—	100	—	—	—	100
Nigeria	33	—	—	67	38	61	—	1
Pakistan	51	—	4	45	66	34	—	—
Panama	39	—	—	61	58	3	—	39
Papua New Guinea	30	—	—	70	—	—	—	100
Paraguay	71	—	—	29	100	—	—	—
Peru	60	—	—	40	68	32	—	—
Philippines	21	10	—	69	100	—	—	—
Portugal	58	—	—	42	88	12	—	—
Rwanda	52	—	—	48	—	—	—	100
Senegal	—	—	—	100	79	—	—	21
Sierra Leone	2	—	—	98	—	—	—	100
Singapore	—	—	—	100	. .	. .	. .	. .
Somalia	—	—	—	100	—	—	—	100
Sri Lanka	78	—	—	22	71	—	—	29
Sudan	53	—	—	47	36	11	—	53
Tanzania	66	—	—	34	—	12	—	88
Thailand	33	—	—	67	89	8	—	3
Trinidad and Tobago	—	—	—	100	. .	. .	. .	. .
Tunisia	3	—	—	97	40	57	—	3
Turkey	42	—	—	58	100	—	—	—
Uganda	97	—	—	3	—	—	—	100
Uruguay	45	—	—	55	93	7	—	—
Venezuela	31	—	—	69	53	44	—	3
Yugoslavia	44	—	—	56	*100*	—	—	—
Zaire	94	—	—	6	—	—	—	100
Zambia	95	—	—	5	—	—	—	—
Zimbabwe	60	—	—	40	100	—	—	—

Note: Figures in *italics* are for 1979. An asterisk indicates the inclusion of gas turbines.

9 Electricity Sales

Country	Total (gWh)	Distribution of total sales, 1980 (percent)					
		Residential	Commercial	Agriculture	Industry	Government	Others
Algeria	5,448	27	6	7	52	6	2
Angola	..	..	..	..	..	..	..
Argentina	31,043	28	9	..	51	12	..
Bangladesh	1,383	16	14	3	64	..	3
Benin	99	60	..	..	40	..	..
Bolivia	1,377	29	..	..	56	..	15
Brazil	112,086	20	12	..	55	..	*13*
Burundi	40	38	35	..	..	15	12
Cameroon	1,292	19	1	..	20	..	60
Chile	8,094	24	9	..	52	15	..
China	230,244	..	7	17	75	..	1
Colombia	15,306	41	12	..	29	8	10
Congo, P.R.	..	..	..	..	..	..	..
Costa Rica	1,879	45	19	..	34	..	2
Dominican Rep.	1,914	38	12	..	38	12	..
Ecuador	2,930	39	14	..	38	9	..
Egypt	16,129	11	59	5	..	..	25
El Salvador	1,272	31	17	..	42	10	..
Ethiopia	430	38	20	..	40	..	*2*
Gabon	..	..	..	..	..	..	..
Ghana	5,180	11	6	..	11	..	72
Greece	..	..	..	..	..	..	..
Guatemala	1,236	25	19	..	42	14	..
Haiti	218	37	5	..	49	4	5
Honduras	761	28	15	..	50	7	..
Hong Kong	..	..	..	..	..	..	..
India	80,000	11	5	17	60	..	*7*
Indonesia	6,502	45	14	..	3	3	35
Iran	..	..	..	..	..	..	..
Iraq	..	..	..	..	..	..	..
Ivory Coast	1,522	45	*48*	..	7	..	..
Jamaica	1,024	31	*56*	..	..	..	*13*
Kenya	1,469	27	*64*	..	..	1	8
Korea, Rep. of	32,735	16	14	1	69	..	..
Malawi	354	16	11	..	73	..	..
Malaysia	7,265	16	30	..	42	..	12
Mexico	52,611	18	75	..	..	7	..
Morocco	3,955	25	5	..	49	5	16
Mozambique	..	..	..	..	..	..	..
Nepal	161	47	16	..	32	5	..
Nicaragua	774	26	9	..	31	34	..
Niger	226	38	26	..	..	26	20
Nigeria	4,596	*50*	*17*	..	33	..	..
Pakistan	8,454	22	3	25	38	1	11
Panama	1,955	26	27	..	26	..	*21*
Papua New Guinea	409	29	59	..	12	..	..
Paraguay	651	53	40	..	4	..	3
Peru	7,462	35	18	..	42	5	..
Philippines	13,719	21	34	..	40	5	..
Portugal	13,733	*18*	28	..	28	25	1
Rwanda	58	22	28	..	33	17	..
Senegal	534	33	49	..	18	..	..
Sierra Leone	108	31	69	..	..	..	..
Singapore	..	..	..	..	..	..	..
Somalia	..	..	..	..	..	..	..
Sri Lanka	1,396	14	16	..	45	25	..
Sudan	758	36	38	8	18	..	..
Tanzania	732	21	12	..	66	1	..
Thailand	13,007	22	27	..	47	..	*4*
Trinidad and Tobago	1,575	30	12	..	57	1	..
Tunisia	2,071	31	10	5	51	..	3
Turkey	20,968	15	6	..	73	5	1
Uganda	528	15	10	..	19	1	55
Uruguay	2,706	43	16	..	35	..	6
Venezuela	27,076	22	11	..	51	15	1
Yugoslavia	51,099	28	8	1	59	2	2
Zaire	3,650	*19*	*78*	..	..	..	3
Zambia	5,417	..	..	..	..	..	..
Zimbabwe	6,801	16	8	5	71	..	..

Note: For explanation of figures in *italics*, see Sources and Technical Notes.

10 Gross Electricity Generation

Country	Total, 1980 (gWh)	Average annual growth rate, 1970–80	Distribution of gross electricity generation by source, 1980 (percent): Liquid fuels	Solid fuels	Natural gas	Hydro	Geothermal	Nuclear
Algeria	6,030	12.1	2	—	91	7	—	—
Angola	1,790	8.8	45	—	—	55	—	—
Argentina	36,980	6.5	36	4	20	34	—	6
Bangladesh	2,318	. .	25	—	49	26	—	—
Benin	109	12.3	18	—	—	82	—	—
Bolivia	1,560	6.7	12	—	20	68	—	—
Brazil	137,000	11.7	7	3	—	90	—	—
Burundi	48	6.2	20	—	—	80	—	—
Cameroon	1,500	1.4	9	—	—	91	—	—
Chile	11,070	4.3	22	16	2	60	—	—
China	300,400	10.9	17	64	—	19	—	—
Colombia	20,580	9.0	3	8	19	70	—	—
Congo P.R.	144	4.7	47	—	—	53	—	—
Costa Rica	2,290	8.0	4	—	—	96	—	—
Dominican Rep.	3,360	13.1	96	2	—	2	—	—
Ecuador	3,700	12.8	73	—	—	27	—	—
Egypt	18,400	9.3	26	—	26	48	—	—
El Salvador	1,410	9.0	2	—	1	71	26	—
Ethiopia	515	2.6	15	—	—	85	—	—
Gabon	140	16.6	100	—	—	—	—	—
Ghana	5,325	4.6	1	—	—	99	—	—
Greece	23,100	8.7	33	48	—	19	—	—
Guatemala	1,470	10.0	81	—	—	19	—	—
Haiti	299	10.3	20	—	—	80	—	—
Honduras	1,230	9.7	19	—	—	81	—	—
Hong Kong	12,600	9.2	100	—	—	—	—	—
India	110,900	6.6	2	50	1	42	—	5
Indonesia	11,000	12.0	73	—	—	27	—	—
Iran	17,100	9.8	41	—	42	17	—	—
Iraq	8,300	11.3	48	—	40	12	—	—
Ivory Coast	1,940	13.3	48	—	—	52	—	—
Jamaica	2,400	4.2	93	2	—	5	—	—
Kenya	1,670	8.1	40	—	—	60	—	—
Korea, Rep. of	36,800	15.3	79	7	—	5	—	9
Malawi	440	10.6	23	—	—	77	—	—
Malaysia	9,620	9.7	86	—	4	10	—	—
Mexico	64,000	8.4	50	—	9	39	2	—
Morocco	5,250	9.4	43	19	—	38	—	—
Mozambique	1,120	7.6	36	—	—	64	—	—
Nepal	229	12.6	9	—	—	91	—	—
Nicaragua	1,061	4.7	54	—	2	44	—	—
Niger	200	9.9	60	—	—	40	—	—
Nigeria	7,250	12.3	6	1	66	27	—	—
Pakistan	15,860	6.3	1	1	36	59	—	3
Panama	1,890	8.8	58	—	—	42	—	—
Papua New Guinea	1,280	21.0	71	—	—	29	—	—
Paraguay	1,020	12.6	2	—	—	98	—	—
Peru	9,780	5.9	31	—	2	67	—	—
Philippines	13,900	7.6	59	1	—	25	15	—
Portugal	15,730	8.4	32	4	—	64	—	—
Rwanda	210	9.3	10	—	—	90	—	—
Senegal	635	7.8	100	—	—	—	—	—
Sierra Leone	230	1.8	96	—	—	4	—	—
Singapore	6,900	12.1	100	—	—	—	—	—
Somalia	110	10.4	100	—	—	—	—	—
Sri Lanka	1,668	7.4	11	—	—	89	—	—
Sudan	940	9.8	36	—	—	64	—	—
Tanzania	990	4.0	19	—	—	81	—	—
Thailand	14,760	13.2	78	9	2	11	—	—
Trinidad and Tobago	1,893	4.3	—	—	100	—	—	—
Tunisia	2,560	13.5	78	—	22	—	—	—
Turkey	24,900	11.1	24	24	—	52	—	—
Uganda	440	−1.6	9	—	—	91	—	—
Uruguay	3,280	4.2	30	—	—	70	—	—
Venezuela	31,400	9.3	25	—	27	48	—	—
Yugoslavia	59,100	8.3	9	44	—	47	—	—
Zaire	4,100	3.5	2	—	—	98	—	—
Zambia	6,410	8.3	—	—	—	100	—	—
Zimbabwe	4,500	−3.4	—	11	—	89	—	—

11 Domestic Retail Petroleum Product Prices and Growth Rates

Country	Domestic petroleum product prices, 1981 (US cents per US gallon)				Average annual growth rate in real domestic terms, 1975–1981			
	Premium gasoline	Kerosene	Diesel oil	Heavy fuel oil	Premium gasoline	Kerosene	Diesel oil	Heavy fuel oil
Algeria	. .	. .	. .	. .	. .	. .	. .	. .
Angola	. .	. .	. .	. .	. .	. .	. .	. .
Argentina	156	94	60	33	−32.5	−11.7	. .	−12.4
Bangladesh	*207*	. .	*74*	. .	. .	. .	. .	. .
Benin	. .	99	138	114	. .	. .	. .	. .
Bolivia	140	61	91	. .	. .	. .	. .	. .
Brazil	. .	150	146	69	. .	. .	. .	. .
Burundi	450	286	305	. .	. .	. .	. .	. .
Cameroon	*240*	. .	*187*	. .	. .	. .	. .	. .
Chile	207	129	170	100	−12.2	−2.7	. .	−11.5
China	. .	*114*	75	*17*	. .	. .	. .	. .
Colombia	96	81	81	. .	9.7	22.8	. .	. .
Congo, P.R.	. .	. .	. .	. .	. .	. .	. .	. .
Costa Rica	. .	84	72	26	. .	. .	. .	. .
Dominican Rep.	257	97	115	72	. .	. .	. .	. .
Ecuador	*80*	*24*	*44*	*28*	. .	. .	. .	. .
Egypt	71	17	14	4	3.9	4.5	−0.1	. .
El Salvador	256	158	170	. .	10.2	12.7	. .	. .
Ethiopia	236	120	99	. .	. .	. .	. .	. .
Gabon	. .	. .	. .	. .	. .	. .	. .	. .
Ghana	394	167	273	103	. .	. .	. .	. .
Greece	237	143	112	54	−6.2	4.0	. .	3.0
Guatemala	*200*	. .	*103*	. .	. .	. .	. .	. .
Haiti	. .	*124*	*117*	*75*	. .	. .	. .	. .
Honduras	*208*	. .	*121*	. .	. .	. .	. .	. .
Hong Kong	. .	. .	. .	. .	. .	. .	. .	. .
India	253	73	119	89	−0.5	−2.2	. .	13.8
Indonesia	133	23	32	27	. .	. .	. .	. .
Iran	216	14	. .	. .	14.6	−12.7	. .	. .
Iraq	. .	. .	. .	. .	. .	. .	. .	. .
Ivory Coast	365	157	250	. .	. .	. .	. .	. .
Jamaica	217	116	135	81	. .	. .	. .	. .
Kenya	274	120	178	70	. .	. .	. .	. .
Korea, Rep. of	582	*160*	*153*	*116*	. .	*8.9*	*8.7*	. .
Malawi	317	219	290	. .	. .	. .	. .	. .
Malaysia	*213*	*83*	*83*	. .	. .	. .	. .	. .
Mexico	110	24	16	7	−5.9	−1.4	. .	−29.1
Morocco	275	146	146	67	. .	. .	. .	. .
Mozambique	. .	. .	. .	. .	. .	. .	. .	. .
Nepal	. .	148	162	. .	. .	. .	. .	. .
Nicaragua	*272*	. .	*145*	. .	. .	. .	. .	. .
Niger	. .	*184*	*218*	. .	. .	. .	. .	. .
Nigeria	*128*	*128*	*120*	*60*	. .	. .	. .	. .
Pakistan	216	105	117	48	6.4	13.2	. .	10.6
Panama	226	129	133	. .	7.4	12.9	. .	. .
Papua New Guinea	. .	*176*	*187*	. .	. .	. .	. .	. .
Paraguay	451	210	174	132	3.7	6.1	. .	4.5
Peru	110	16	58	41	. .	. .	. .	. .
Philippines	250	149	148	99	12.7	9.2	. .	7.9
Portugal	299	134	134	48	2.0	13.2	. .	10.6
Rwanda	*283*	*257*	*271*	. .	. .	. .	. .	. .
Senegal	*302*	*157*	*186*	*74*	. .	. .	. .	. .
Sierra Leone	*238*	*136*	*132*	. .	. .	. .	. .	. .
Singapore	191	121	123	. .	−3.4	4.8	. .	. .
Somalia	. .	. .	. .	. .	. .	. .	. .	. .
Sri Lanka	200	78	119	71	4.2	9.5	. .	17.4
Sudan	*230*	*108*	*62*	*38*	. .	. .	. .	. .
Tanzania	*437*	*160*	*183*	. .	. .	. .	. .	. .
Thailand	214	110	133	79	12.4	7.8	. .	11.0
Trinidad and Tobago	35	14	29	. .	. .	. .	. .	. .
Tunisia	*206*	*44*	. .	*36*	*2.6*	*2.1*	. .	. .
Turkey	174	113	110	71	9.4	7.2	. .	8.1
Uganda	*544*	*290*	*327*	*181*	. .	. .	. .	. .
Uruguay	417	181	170	79	4.7	5.2	. .	3.5
Venezuela	31	9	9	4	−10.4	−22.8	. .	. .
Yugoslavia	*286*	*226*	*241*	*129*	*21.3*	*18.8*	. .	*30.3*
Zaire	. .	. .	. .	. .	. .	. .	. .	. .
Zambia	432	154	223	. .	. .	. .	. .	. .
Zimbabwe	*312*	. .	*206*	. .	. .	. .	. .	. .

Note: For explanation of figures in *italics*, see Sources and Technical Notes.

12 Petroleum Product Price Indicators

Country	Premium gasoline	Kerosene	Diesel oil	Heavy fuel oil	Premium gasoline	Kerosene	Diesel oil	Heavy fuel oil
	Domestic retail prices as a percentage of border prices, 1981				*Domestic retail prices as a percentage of diesel oil retail prices, 1980*			
Algeria	. .	. .	. .	. .	. .	. .	. .	. .
Angola	. .	. .	. .	. .	. .	. .	. .	. .
Argentina	150	91	61	50	260	157	100	55
Bangladesh	*193*	. .	*70*	. .	*280*	. .	*100*	. .
Benin	. .	96	141	173	. .	72	100	83
Bolivia	143	63	100	. .	154	67	100	. .
Brazil	. .	147	151	108	. .	103	100	47
Burundi	181	122	129	. .	148	94	100	. .
Cameroon	*240*	. .	*191*	. .	*128*	. .	*100*	. .
Chile	199	125	173	154	122	76	100	59
China	. .	. .	. .	. .	. .	*152*	*100*	*23*
Colombia	97	83	88	. .	119	100	100	. .
Congo, P.R.	. .	. .	. .	. .	. .	. .	. .	. .
Costa Rica	. .	86	77	43	. .	117	100	36
Dominican Rep.	260	99	125	122	223	84	100	63
Ecuador	*82*	*24*	*48*	*53*	*182*	*55*	*100*	*64*
Egypt	66	15	13	5	507	121	100	29
El Salvador	253	158	179	. .	151	93	100	. .
Ethiopia	217	104	91	. .	238	121	100	. .
Gabon	. .	. .	. .	. .	. .	. .	. .	. .
Ghana	379	162	279	158	144	61	100	38
Greece	210	121	99	67	212	128	100	48
Guatemala	*211*	. .	*112*	. .	*194*	. .	*100*	. .
Haiti	. .	*113*	*121*	*142*	. .	*106*	*100*	*64*
Honduras	*208*	. .	*127*	. .	*172*	. .	*100*	. .
Hong Kong	. .	. .	. .	. .	. .	. .	. .	. .
India	231	64	109	113	213	61	100	75
Indonesia	124	21	30	35	416	72	100	84
Iran	202	13	. .	. .	. .	. .	. .	. .
Iraq	. .	. .	. .	. .	. .	. .	. .	. .
Ivory Coast	351	154	258	. .	146	63	100	67
Jamaica	*219*	*118*	145	135	161	86	*100*	60
Kenya	249	103	160	90	154	67	100	39
Korea, Rep. of	*539*	*139*	*137*	*151*	*380*	*105*	*100*	*76*
Malawi	225	158	216	. .	109	76	100	. .
Malaysia	*205*	*78*	*81*	. .	*257*	*100*	*100*	. .
Mexico	112	25	18	12	688	150	100	44
Morocco	267	143	151	103	188	100	100	46
Mozambique	. .	. .	. .	. .	. .	. .	. .	. .
Nepal	. .	. .	. .	. .	. .	91	100	. .
Nicaragua	*267*	. .	*151*	. .	*188*	. .	*100*	. .
Niger	. .	. .	. .	. .	. .	*84*	*100*	. .
Nigeria	*125*	*116*	*115*	*90*	*107*	*107*	*100*	*50*
Pakistan	200	93	108	63	185	90	100	41
Panama	226	132	143	. .	170	97	100	. .
Papua New Guinea	. .	*152*	*165*	. .	. .	*94*	*100*	. .
Paraguay	. .	. .	. .	. .	259	121	100	76
Peru	112	16	64	71	190	26	100	71
Philippines	229	132	136	122	169	101	100	67
Portugal	290	131	138	75	223	100	100	36
Rwanda	*121*	*115*	*123*	. .	*104*	*95*	*100*	. .
Senegal	*311*	*160*	*202*	*116*	*162*	*84*	*100*	*40*
Sierra Leone	*243*	*125*	*138*	. .	*180*	*103*	*100*	. .
Singapore	179	110	115	. .	155	98	100	. .
Somalia	. .	. .	. .	. .	. .	. .	. .	. .
Sri Lanka	182	69	108	88	168	66	100	60
Sudan	*219*	*95*	*57*	*53*	*371*	*174*	*100*	*61*
Tanzania	*412*	*144*	*173*	. .	*239*	*87*	*100*	. .
Thailand	196	98	122	99	161	83	100	59
Trinidad and Tobago	36	14	32	. .	121	48	100	. .
Tunisia	*196*	*38*	. .	*53*	. .	. .	. .	. .
Turkey	154	95	96	87	158	103	100	65
Uganda	. .	. .	. .	. .	*166*	*87*	*100*	*55*
Uruguay	401	176	173	120	245	106	100	46
Venezuela	32	9	10	7	344	100	100	44
Yugoslavia	255	*184*	*206*	*165*	*119*	*94*	*100*	*54*
Zaire	. .	. .	. .	. .	. .	. .	. .	. .
Zambia	. .	. .	. .	. .	194	69	100	. .
Zimbabwe	. .	. .	. .	. .	*151*	. .	*100*	. .

Note: For explanation of figures in *italics*, see Sources and Technical Notes for table 11.

13 Petroleum Exploration Activity

Country	Seismic activity, 1980					Footage drilled, 1980		Exploratory wells completed, 1981	Exploratory and development wells completed, 1981	Active rigs, 1982
	Land		Marine		Total, line kilometer	Depth drilled (thousand feet)	Average depth (feet)			
	Crew months	Line kilometer	Crew months	Line kilometer						
Algeria	300	22,500	--	--	22,500	. .	. .	1	. .	68
Angola	6	701	5	12,500	13,201	133	10,231	. .	. .	8
Argentina	275	22,423	18	36,866	59,289	. .	. .	. .	. .	73
Bangladesh	28	2,100	--	--	2,100	. .	. .	3	3	3
Benin	--	--	--	--	--	--	--	--	--	--
Bolivia	11	1,064	--	--	1,064	242	10,522	19	39	13
Brazil	133	9,939	45	64,435	74,374	2,500	6,083	. .	. .	93
Burundi	--	--	--	--	--	--	--	--	. .	--
Cameroon	14	986	7	3,825	4,811	310	7,046	. .	. .	6
Chile	30	2,000	2	1,700	3,700	570	7,500	. .	. .	7
China	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Colombia	63	7,091	--	191	7,282	782	6,358	60	185	23
Congo, P.R.	5	408	4	5,465	5,873	214	5,632	22	39	7
Costa Rica	--	--	--	--	--	--	--	--	--	--
Dominican Rep.	2	180	--	--	180	--	--	1	1	--
Ecuador	11	800	. .	. .	800	. .	. .	. .	30	5
Egypt	47	7,300	13	15,000	22,300	762	9,181	64	113	32
El Salvador	--	--	--	--	--	--	--	--	--	--
Ethiopia	--	--	--	--	--	--	--	--	--	--
Gabon	8	681	7	12,619	13,300	292	7,300	. .	. .	15
Ghana	--	--	1	500	500	9	9,000	2	2	--
Greece	30	1,003	2	928	1,931	. .	. .	. .	. .	6
Guatemala	9	600	--	--	600	50	12,500	. .	. .	--
Haiti	2	230	. .	. .	230	--	--	--	--	--
Honduras	--	--	--	--	--	13	6,500	--	--	--
Hong Kong	--	--	--	--	--	--	--	--	--	--
India	250	5,400	14	14,350	19,750	. .	. .	10	. .	47
Indonesia	221	16,380	18	34,247	50,627	3,208	5,084	170	618	94
Iran	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Iraq	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Ivory Coast	--	--	1	3,080	3,080	67	8,375	. .	. .	6
Jamaica	--	--	--	--	--	--	--	1	--	--
Kenya	--	--	1	3,087	3,087	--	--	1	1	--
Korea, Rep. of	--	--	1	25,818	2,518	--	--	1	1	--
Malawi	--	--	--	--	--	--	--	--	--	--
Malaysia	5	400	10	15,440	15,840	802	7,495	61	82	14
Mexico	312	23,400	60	90,000	113,400	4,105	7,909	60	412	211
Morocco	19	1,873	--	--	1,873	91	9,100	14	14	6
Mozambique	--	--	--	--	--	--	--	--	--	--
Nepal	--	--	--	--	--	--	--	1	1	--
Nicaragua	--	--	1	1,500	1,500	--	--	--	--	--
Niger	--	--	--	--	--	26	8,667	--	--	5
Nigeria	109	7,462	9	13,000	20,462	1,375	9,549	. .	. .	28
Pakistan	90	7,500	--	--	7,500	137	7,611	12	24	16
Panama	--	--	--	--	--	--	--	1	1	--
Papua New Guinea	--	--	--	--	--	10	10,000	1	1	1
Paraguay	8	600	--	--	600	--	--	1	1	1
Peru	20	945	1	800	1,745	846	5,853	17	172	26
Philippines	12	945	35	20,244	21,189	190	7,600	. .	. .	18
Portugal	4	270	--	--	270	. .	. .	1	. .	--
Rwanda	--	--	--	--	--	--	--	--	--	--
Senegal	4	300	5	7,500	7,800	--	--	--	--	--
Sierra Leone	--	--	2	2,500	2,500	--	--	--	--	--
Singapore	--	--	--	--	--	--	--	--	--	--
Somalia	19	1,400	1	1,180	2,580	4	4,000	--	--	--
Sri Lanka	--	--	1	1,555	1,555	--	--	2	2	--
Sudan	24	4,000	1	2,077	6,077	. .	. .	14	14	2
Tanzania	. .	. .	. .	. .	. .	--	--	3	3	--
Thailand	. .	. .	. .	. .	. .	227	9,080	19	. .	9
Trinidad and Tobago	. .	. .	10	14,690	14,690	675	3,649	. .	. .	13
Tunisia	50	7,700	4	8,900	16,600	158	10,533	33	36	11
Turkey	31	2,300	1	1,500	3,800	. .	. .	. .	. .	26
Uganda	--	--	--	--	--	--	--	--	--	--
Uruguay	--	--	--	--	--	--	--	. .	. .	--
Venezuela	40	5,000	3	6,000	11,000	5,940	7,122	52	742	68
Yugoslavia	--	--	--	--	--	--	--	--	--	22
Zaire	--	--	--	--	--	17	8,500	6	8	--
Zambia	--	--	--	--	--	--	--	--	--	--
Zimbabwe	--	--	--	--	--	--	--	--	--	--

Note: -- No activity known or assumed.
. . Not available (activity known or assumed).

14 Refining Charge Capacity

Country	Crude	Vacuum distillation	Thermal operations	Catalytic cracking	Reforming	Hydrocracking	Hydrofining	Hydrotreating
	Charge capacity, 1982 (thousand barrels per calendar day)							
Algeria	137	6	..	..	24	..	..	24
Angola	32	2	..	..	2	..	3	4
Argentina	676	181	55	99	38	19	..	33
Bangladesh	31	3	..	..	2	..	..	4
Benin	..	..	..	..	..	..	..	..
Bolivia	61	2	..	..	13	..	..	..
Brazil	1,219	612	16	277	22	..	..	98
Burundi	..	..	..	..	..	..	..	..
Cameroon	43	..	..	..	7	..	10	10
Chile	141	74	8	34	9	..	..	..
China	2,000	..	..	..	..	..	..	..
Colombia	214	120	41	77	6	..	..	34
Congo, P.R.	..	..	..	..	..	..	..	..
Costa Rica	16	1	..	..	2	..	..	4
Dominican Rep.	48	..	..	..	8	..	..	22
Ecuador	79	26	11	11	3	..	..	..
Egypt	341	29	..	..	11	..	2	43
El Salvador	16	2	..	..	3	..	..	12
Ethiopia	14	3	..	..	2	..	..	2
Gabon	20	..	7	..	1	..	..	5
Ghana	27	..	..	..	6	..	..	..
Greece	422	58	11	23	30	..	27	101
Guatemala	16	..	..	..	3	..	..	5
Haiti	..	..	..	..	..	..	..	..
Honduras	14	..	..	..	2	..	..	5
Hong Kong	..	..	..	..	..	..	..	..
India	753	184	86	74	15	..	48	45
Indonesia	341	67	19	12	23	..	..	18
Iran	530	215	81	..	64	93	3	34
Iraq	169	..	..	..	5	..	..	13
Ivory Coast	90	41	..	..	15	..	..	42
Jamaica	36	2	..	..	4	..	..	22
Kenya	79	..	..	..	9	..	..	31
Korea Rep. of	755	28	13	..	37	6	14	69
Malawi	..	..	..	..	..	..	..	..
Malaysia	175	3	..	..	10	..	13	33
Mexico	1,289	593	123	298	164	18	..	476
Morocco	74	2	..	..	9	..	2	7
Mozambique	16	..	..	..	..	..	..	..
Nepal	..	..	..	..	..	..	..	..
Nicaragua	14	2	..	..	3	..	..	11
Niger	..	..	..	..	..	..	..	..
Nigeria	260	70	..	47	24	..	..	66
Pakistan	133	7	..	..	5	..	..	30
Panama	100	14	..	..	8	..	..	30
Papua New Guinea	..	..	..	..	..	..	..	..
Paraguay	8	..	..	..	..	..	..	..
Peru	168	33	..	37	2	..	..	2
Philippines	286	38	..	23	40	..	24	93
Portugal	365	32	..	..	54	10	9	131
Rwanda	..	..	..	...	..	..	..	..
Senegal	18	..	..	..	2	..	..	2
Sierra Leone	10	..	..	..	..	..	..	..
Singapore	1.096	161	105	..	39	16	35	331
Somalia	10	..	..	..	..	..	..	..
Sri Lanka	50	2	13	..	4	..	2	15
Sudan	24	..	..	..	2	..	..	9
Tanzania	17	..	..	..	4	..	..	5
Thailand	176	12	12	9	25	..	35	65
Trinidad and Tobago	375	173	..	25	27	..	80	58
Tunisia	34	..	..	..	3	..	..	..
Turkey	467	121	..	41	44	..	..	143
Uganda	..	..	..	..	..	..	..	..
Uruguay	45	12	..	5	3	..	..	8
Venezuela	1,284	572	82	178	8	..	307	..
Yugoslavia	297	38	6	2	45	7	14	27
Zaire	17	..	..	..	4	..	..	5
Zambia	25	2	..	..	6	..	..	9
Zimbabwe	..	..	..	..	..	..	..	..

Sources and Technical Notes

These energy indicators provide selected economic and energy information for 69 developing countries in a form suitable for comparing economies. The coverage of developing countries has been governed mainly by the availability of data. Although the statistics and measures have been carefully selected to provide a comprehensive picture of the energy sector, readers are urged to exercise care in interpreting them, since statistical methods, coverage, practices, and definitions may differ among countries.

To facilitate comparisons, production, consumption, and trade of commercial primary energy are presented in tons of oil equivalent (toe). The conversion factors used are shown on page xvi.

Annual average growth rates are compounded growth rates from the beginning to the end period.

Table 1. Basic Indicators

Population figures are mid-year estimates prepared from material obtained from the UN Population Division, the U.S. Bureau of the Census, and the World Bank's own data files.

The *gross national product (GNP) per capita* figures were calculated according to the *World Bank Atlas* method, by dividing GNP at market prices in US dollars by the population in mid-1980. GNP measures the total domestic and foreign output claimed by residents. It comprises gross domestic product and factor incomes (such as investment income and workers' remittances) accruing to residents living abroad, less the income earned in the domestic economy accruing to nonresidents.

Gross domestic product (GDP) measures the total final output of goods and services produced by an economy—that is, by residents and nonresidents alike, regardless of the allocation to domestic and foreign claims. GDP at factor cost is equal to GDP at market prices, less indirect taxes net of subsidies.

Industry as percentage share of GDP is obtained by dividing industry data by the GDP of the respective country. For our purposes, industry comprises mining, manufacturing, and construction, as well as electricity, water, and gas.

Net fuel exports (imports) figures are measured in US dollars and computed by subtracting imports from exports. Fuel comprises oil, gas, electricity, and coal.

All data, except the population figures, were drawn from the UN *Commodity Trade Data Base* and the World Bank.

Figures in italics are for years other than 1980. *Industry percentage share of GDP* data for Iran and Nepal are for 1977; for Iraq, Papua New Guinea, and Somalia, they are for 1979. Data on *net fuel exports (imports) as a percentage of total merchandise imports* and *exports* for Ivory Coast are for 1981; for Bolivia, Burundi, Chile, Congo, P.R., Gabon, India, Mexico, Nigeria, Paraguay, and Somalia, they are for 1979; for Bangladesh, Ghana, Iraq, Zaire, and Zambia, they are for 1978; for Benin, Iran, and Mozambique, they are for 1977; and for Angola, they are for 1974. In addition, *net fuel exports (imports)* data for Benin, Bolivia, Burundi, Mexico, and Mozambique are estimates.

Table 2. Commercial Primary Energy Indicators

Consumption refers to apparent consumption, which is computed by subtracting exports and then adding imports to domestic production. Bunkers are treated as the consumption of the supplying country irrespective of the flag of the carrier receiving the fuel.

Energy consumption per capita is obtained by dividing commercial primary energy consumption by the population shown in Table 1.

Energy consumption per unit of GDP is computed by dividing commercial primary energy consumption by GDP in US dollars.

Data on commercial energy production and trade are from the United Nations *Yearbook of World Energy Statistics* and the World Bank.

Figures in italics indicate a decrease in *energy consumption per unit GDP* in 1980 as compared to 1970. In Hong Kong, Kenya, and Malaysia it decreased on account of labor-intensive growth; in Singapore, Trinidad and Tobago, and Venezuela, it decreased on account of a decrease or stagnation in refining.

Tables 3, 4, and 5. Commercial Primary Energy Production, Consumption, and Trade, by Type of Fuel

These tables show commercial primary energy production, consumption, and trade for liquid fuels (crude and petroleum products), solid fuels (coal, lignite, and peat), natural gas, and primary electricity. Production of liquid fuels refers to primary production, that is crude oil including natural gas liquids.

Data are drawn from the UN *Yearbook of World Energy Statistics* and the World Bank.

In some cases, figures for the distribution of production and consumption of solid fuels and primary electricity are small relative to other fuels so that they constitute less than 0.5 percent and are shown as negligible. However, for the purpose of indicating the trend, average annual growth rates are shown in these cases.

Table 6. Energy Reserves and Potential

Proven crude oil and natural gas reserves data estimate quantities of oil and gas remaining in the ground indicated by geological and engineering information; these quantities of oil and gas are recoverable with existing technology and under existing economic conditions without constraints imposed by current demand (particularly for natural gas). These data are drawn from the *Oil and Gas Journal, BP Statistical Review, World Oil*, and the World Bank. Crude oil reserves include natural gas liquids.

Coal reserves are the technically and economically recoverable quantities of solid fuels remaining in the ground and are expressed in tons of coal equivalent (tce); these figures are drawn from the *World Energy Conference*, 1977.

The *hydroelectric potential* refers to the total, estimated, technically exploitable hydroelectric capacity for the country based on all practicable sites for head development and assuming average waterflows. These figures are World Bank estimates.

The table identifies countries with *geothermal potential* as those where geothermal projects have been completed or are under construction, as well as countries with economic potential for geothermal development. These data are from World Bank sources.

Tables 7 and 8. Installed Power Capacity

Installed power capacity refers to the rated capacity as stated on the name plate of the equipment in the power plant. It includes the total public capacity and autogeneration by private consumers. However, data for autogeneration may be incomplete since they tend to be unreliable and scanty. Available or effective capacity is usually less than the rated capacity and decreases as equipment deteriorates. The *thermal capacity* uses oil, gas, coal, and lignite, and it comprises steam, gas turbines, combined cycle, and diesel plants. Total generation capacity includes autogeneration; thermal generation capacity excludes it. All data were drawn from the World Bank.

Table 9. Electricity Sales

Electricity sales data refer to the actual metered amount of electricity billed to consumers. The difference between electricity generation and sales is accounted for by technical and nontechnical losses during transmission and distribution.

Technical losses are due to the electrical characteristics of the power system and the amount of load on the system. They consist mainly of resistance losses occurring on the transmission and distribution systems while transporting electricity from generating plants to the consumers.

Nontechnical losses consist mainly of unmetered consumption in the distribution process. In many developing countries, up to 60 to 80 percent of the losses occur in the distribution phases.

Electricity sales to government refer mainly to government office buildings. However, hospitals, schools, street lighting, and other preferential customers may also be included.

All data were drawn from the World Bank.

Data on the *distribution of total sales* for Ivory Coast, Nigeria, Portugal, and Rwanda by sector were not available. In these cases, low voltage sales have been attributed to residential use, medium voltage sales to commercial use, and high voltage sales to industrial use. They are shown in italics. Also in italics are figures for the distribution of total sales to "others" which include sales to government for Brazil, Egypt, Ethiopia, Jamaica, Panama, Paraguay, and Thailand. Figures in italics for the distribution of total sales to the commercial sector include sales to industry for Burundi, Egypt, Jamaica, Kenya, Mexico, and Sierra Leone.

Note that low, medium, and high voltage may be classified differently from country to country. In this report, the classification is as follows:

High voltage	=	above 66 kV
Medium voltage	=	2.4–34 kV
Low voltage	=	110–380 volts

Table 10. Gross Electricity Generation

Gross electricity generation is electricity generated as reported by the power companies on the basis of available monthly metering records. It includes station use (the amount of electricity consumed by the power plant itself) and losses. Net electricity generation would exclude electricity consumed by the power plant, but would include losses. *Average annual growth rate* of gross electricity generation between 1970 and 1980 is computed using UN data. Figures other than the average annual growth rates are for 1980 and were obtained from World Bank reports.

Table 11. Domestic Retail Petroleum Product Prices and Growth Rates

Domestic petroleum product prices figures represent the actual retail prices paid by consumers; they usually incorporate ex-refinery prices, domestic taxes or subsidies, and marketing and distribution margins. Where products are imported, the price includes cost, insurance, and freight; import duties; domestic taxes or subsidies; and marketing and distribution margins.

Annual average growth rates for domestic petroleum prices is compounded growth rates between 1975 and 1981. They are expressed in domestic currency and in real terms. The 1975 and 1981 domestic prices, originally reported in US dollars, were converted to local currency by using the official currency exchange rate for the respective year published in the *International Financial Statistics* (IFS) by the International Monetary Fund. Values stated in 1975 terms were inflated to the 1981 levels using the wholesale price index published in the IFS.

Data for this table were drawn from *Energy Week*, *International Energy Annual*, the UN *Yearbook of World Energy Statistics*, and the World Bank.

The period reported is the third quarter of 1981. Exceptions are in italics, and they refer to periods ranging from 1980 to 1982. Data for Ecuador and Rwanda are for the first quarter of 1981. Data for Papua New Guinea are for the fourth quarter of 1981. Data for Bangladesh, Cameroon, China, Guatemala, Haiti, Malaysia, Niger, Sierra Leone, Tanzania, and Zimbabwe are for 1980. Data for Honduras, Korea, Nicaragua, Nigeria, Senegal, Sudan, Tunisia, Uganda, and Yugoslavia are for 1982. *Average annual growth rates* for Korea, Tunisia, and Yugoslavia cover the six-year period between 1976 and 1982.

Table 12. Petroleum Product Price Indicators

Domestic retail prices as a percentage of border prices relates domestic prices defined in Table 11 to c.i.f. import prices for importers or f.o.b. prices for exporters. This percentage was obtained by using the retail petroleum product prices from Table 11 and the border price for the corresponding quarter.

Domestic retail prices as a percentage of diesel oil retail prices relates the domestic petroleum prices defined in Table 11 to diesel oil prices; diesel oil includes gas oil.

Figures in italics range from 1980 to 1982, and are not for the third quarter of 1981.

Table 13. Petroleum Exploration Activity

Land seismic activity typically includes surveys conducted on land, in swamps, and under rivers. *Marine seismic activity* typically includes surveys conducted in shallow and deep water areas. Figures for lakes are also included in marine seismic activity.

Footage drilled refers to the depth drilled. It is derived by adding total exploratory drilling footage to total development drilling footage. All footage drilled is included regardless of whether or not the well is completed.

Exploratory wells completed refers primarily to wildcat wells—those drilled in areas not known to be productive. Not included are stratigraphic tests, suspended wells, appraisal wells, extension wells, and development wells. Included in the completion total are abandoned wells, oil or gas wells, and dry wells.

Total exploratory and development wells completed refers to the sum of all exploration and development wells completed within the year designated. All spudded wells, respudded wells, sidetracked holes, and deviated holes are counted as single units.

Average depth per well completed is an approximate value derived by taking total footage drilled (rounded to the nearest thousand) and dividing it by total wells completed (exploratory and development).

Active rigs refers to rigs making new holes and excludes rigs on workovers.

All data are World Bank estimates.

Table 14. Refining Charge Capacity

This table indicates the various refining processes presently in operation as of January 1, 1983 (see Glossary for definitions of the refining processes). A variety of refining processes is necessary to best match the slate of products (processed from a given crude oil or a mix of crudes) with the demand for the different products.

Charge capacity is the potential refining capacity of the plant rather than the actual amount of products produced by each technology. The figures represent the average volume refinery units process each day, including downtime used for maintenance. This is the total volume for the year divided by 365.

All data are from the *Oil and Gas Journal*, December 1982.

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