

Energy Supply and Demand Balances and Financing Requirements in Non-OPEC Developing Nations

Final Report

February 1979

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Under Contract No. EH-77-C-01-6407


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Price: Printed copy: \$ 9.00
Microfiche: \$3.00

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EXECUTIVE SUMMARY

BACKGROUND

This report examines the key aspects of the energy supply and demand situation in developing countries. It begins by defining five categories that reflect the differences among these countries' economic and resource structures, their levels of development, and the energy options available to them. For each country group, the energy supply and demand is projected, by fuel type, to the years 1990 and 2020. On the basis of the available estimates of resource development costs, we have quantified the financial requirements for these countries to achieve aggregate energy self-sufficiency. The analysis is extended through a consideration of the determinants and sources of investment capital for energy development.

A principal factor influencing the energy balances of "less developed countries" (LDCs) will be government policies in such areas as energy conservation, growth strategies, and international economic relations. This study addresses the question of possible LDC responses to energy shortages in three respects. First, energy conservation and fuel switching alternatives are examined for industry, transportation, the urban residential sector, and the rural and agricultural sector. Second, small scale technologies for renewable energy resources are discussed in terms of their potential applications for LDCs. Finally, each LDC country group's range of likely responses to energy shortages is examined in terms of both historical patterns and resource constraints.

NATURE OF THE PROBLEM

The future energy supply and demand balances in LDCs will help to shape the worldwide energy outlook, as well as these nations' prospects for development as a group and as individual countries. Further, the LDCs' energy situations will have both direct and indirect impacts on the United States' interests and policies. These impacts may arise through several channels:

- . increased LDC dependence on existing sources of energy supply, particularly on energy supplied by OPEC nations.
- . potential energy supply expansion and diversification through resource development in non-OPEC LDCs.
- . effects of possible energy shortages on economic growth in developing countries, and therefore on the satisfaction of the basic human needs of their populations.

- . Impacts of LDC growth trends on the trade, private investment, and the economic growth outlook in industrialized nations.
- . Political and social instability that may be caused by energy-related bottlenecks to economic growth in LDCs.

In this context, the energy situation in developing countries requires particular attention for several reasons. First, although they start from a relatively low base, LDCs are the fastest growing group of nations in terms of energy consumption. Their energy consumption growth will be particularly pronounced if it is assumed that "basic human needs" (food, nutrition, health services, economic security) will be met for all of the world's people. Second, many of the poorest LDCs have been seriously affected by the energy price rise of 1973-74 and may not be able to finance their growing oil import requirements without further limiting their economic development potential. To the extent that this is true, combinations of less energy-intensive development approaches, lower cost indigenous production, and/or external financial assistance must be developed to minimize the impact of energy shortages on these countries. Third, recent studies suggest that while non-OPEC LDCs as a group may have the potential to increase their energy production significantly, this increase can occur only if internal technical and institutional constraints can be overcome and if the massive external financing requirements implied by such increased production can be met. The bulk of such financing must come from public and private sources in the developed countries. The basic issue of whether all LDCs will believe it is in their interest to develop their energy resources as rapidly as possible must be addressed. Finally, potentially large-scale resource development has been impeded by institutional constraints in LDCs; steps towards removing these constraints can be facilitated by a better understanding of future LDC energy prospects.

CHARACTERISTICS OF THE NON-OPEC LDCs

The non-OPEC LDCs analyzed in this report are a disparate group of 87 nations located primarily in Asia, Africa and Latin America. The measure usually relied upon to identify an LDC is low Gross National Product (or alternatively, low Gross Domestic Product) per capita. However, GNP is only one, imperfect measure of an LDC's economic position. It is symptomatic of a wide range of socioeconomic characteristics generally common, albeit with varying degrees of intensity, to most LDCs. At a highly generalized level, the important prevalent characteristics of most LDCs include:

- . low GNP per capita (relative to developed nations),
- . relatively great income inequality, with large percentages of the population living at or near subsistence levels,
- . predominance of the pre-industrial sectors and non-integration, of the traditional and modern sectors,
- . inadequate physical and social infrastructure,

- . high population growth rates, which have frequently constrained per capita GNP growth, and
- . low domestic savings and limited markets, with consequent dependence upon foreign capital, producer and consumer goods, and export markets.

We have categorized the 87 developing nations into five relatively homogeneous groups which are more consistent with their development and energy choices than the usual high, middle, and low income categories. These new groupings reflect their varying present stages and patterns of development implied by annual per capita income, income distribution, industrialization, urbanization, and such social indicators as infant mortality. However, the categories are primarily based on the characteristic economic and resource structures which determine the basic energy options available to them. Exhibit 1 shows the country groupings.

1. Industrialized Countries are those in which industry is the largest sector in terms of percent of Gross Domestic Product (GDP), but where the modern (and predominantly urban) industrial sector is independent from the traditional urban and rural sectors.
2. Balanced Growth Economies are those in which the industrial sector is relatively developed but not dominant in terms of contribution to GDP, giving them considerable potential for flexibility in pursuing their future development strategies.
3. Primary Exporters are countries in which minerals account for the bulk of total exports and are a major contributor to GDP. But as a group, their mean GNP per capita is considerably lower than the industrialized and balanced economy countries.
4. Agricultural Economies are those countries in which agricultural output clearly dominates GDP. This group includes both the exporting and basic agricultural economies found in east and west Africa, most of Central America, and throughout Asia and South America.
5. Current (non-OPEC) Oil Exporters. These countries are addressed in only a preliminary way since their energy choices are quite different from the other countries considered here.

DEMAND AND SUPPLY FORECASTS

Demand

Gordian has estimated the demand for commercial primary energy -- oil, natural gas, primary electricity (hydropower, nuclear, and geothermal), and

EXHIBIT 1. COUNTRY CATEGORIES

Industrialized Countries

Argentina
 Brazil
 Chile
 Republic of Korea
 Singapore
 Spain
 Taiwan
 Uruguay
 Yugoslavia

Balanced Growth Economies

Colombia
 Greece
 India
 Pakistan
 Panama
 Peru
 Philippines
 Turkey

Primary Exporters

Botswana
 Guinea
 Guyana
 Jamaica
 Liberia
 Mauritania
 Morocco
 Sierra Leone
 Togo
 Zaire
 Zambia

Agriculturally Oriented EconomiesAgricultural Exporters

Costa Rica
 Dominican Republic
 Gambia
 Guatemala
 Honduras
 Ivory Coast
 Senegal
 Sri Lanka
 Thailand

Other Agricultural

Afghanistan
 Bangladesh
 Benin
 Burma
 Burundi
 Cameroon
 Central African Empire
 Chad
 Comoros
 Cyprus
 El Salvador
 Eq. Guinea
 Ethiopia
 Fiji
 Ghana
 Haiti
 Jordan
 Kenya
 Lebanon
 Lesotho
 Madagascar
 Malawi
 Mali
 Mauritius
 Mozambique
 Nepal
 Nicaragua
 Niger
 Papua New Guinea
 Paraguay
 Rwanda
 Somalia
 Sudan
 Surinam
 Swaziland
 Tanzania
 Uganda
 Upper Volta
 Yemen Arab Republic

EXHIBIT 1. (cont'd.)

Current Oil Exporters

Angola
Bolivia
Brunei
Peoples Republic of Congo
Egypt
Malaysia
Mexico
Oman
Syrian Arab Republic
Trinidad/Tobago
Tunisia

coal -- for each LDC group to the year 2020. Crude estimates of noncommercial energy demand, developed jointly by Gordian Associates, Brookhaven National Laboratory, and the overseas Development Council are also included.

Two forecasting assumptions were made for commercial primary energy. The "increasing real energy prices case" assumes a gradual reduction in GNP growth to 2020, and real energy price increases of 50% by 1990 and 100% by 2000. The assumed price elasticity of demand is 0.3. The "increasing real energy prices case" which may be regarded as a conservative forecast, yields a total non-OPEC LDC energy demand of 55,095,000 barrels of oil per day equivalent (BDOE) by 2020. The "constant real energy prices case" is based on the assumption that there will be only very slight reductions in GNP growth and that energy prices will remain constant in real terms during the forecasting period. Demand in this case is projected to be 113,103,000 BDOE by 2020. The projections for the two cases are presented in Exhibit 2. Breakdowns of demand by country category and by geographic region are presented in Exhibits 3 and 4, respectively. A comparative analysis of Gordian's demand projections in relation to those developed by other organizations (WAES, World Bank, CIA, Energy Information Administration, etc.) is included as Exhibit 4a.

Noncommercial energy includes, principally: wood, cowdung, crop residues, and animal power. Scant data is available on noncommercial energy consumption; existing evidence suggests that it constitutes over 50% of the energy use in many LDCs, playing an especially important role in their rural areas. Our demand estimates are based on the assumption of minimum consumption requirements of 400 kilograms of coal equivalent per year. The projected demand levels for noncommercial energy are shown in Exhibit 5.

EXHIBIT 2. PROJECTED COMMERCIAL ENERGY CONSUMPTION FOR NON-OPEC LDCs
(Thousands of Barrels of Oil Equivalent Per Day)

<u>Increasing Real Energy Prices Case</u>				
<u>Fuel Type</u>	<u>1976</u>	<u>1990</u>	<u>2000*</u>	<u>2020*</u>
Oil	6070	11290	14148	27927
Coal	2552	5664	7864	19063
Primary Electricity	444	1321	1848	4571
Natural Gas	<u>723</u>	<u>1583</u>	<u>2144</u>	<u>3534</u>
Total	9789	19858	26004	55095
<u>Constant Real Energy Prices Case</u>				
Oil	6070	12015	19920	56607
Coal	2552	5805	10972	38072
Primary Electricity	444	1270	2414	8505
Natural Gas	<u>723</u>	<u>1664</u>	<u>3008</u>	<u>9919</u>
Total	9789	20754	36314	113103

* Adjusted for real price increases

Source: 1975 consumption data from United Nations Statistical Paper, Series J. No. 20. World Energy Supplies 1971-75, New York.

Projections are Gordian Associates estimates.

EXHIBIT 3. PROJECTED NON-OPEC COMMERCIAL ENERGY CONSUMPTION BY COUNTRY CATEGORY
(Thousands of Barrels of Oil Equivalent Per Day)

Increasing Real Energy Prices Case

	<u>1976</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
Industrialized	4132	7886	10155	21328
Balanced Growth Economies	3176	7240	9678	21659
Primary Exporters	213	335	379	606
Agricultural Economies	685	1060	1198	1918
Oil Exporters	<u>1586</u>	<u>3337</u>	<u>4594</u>	<u>9584</u>
Total	9792	19858	26004	55095

Constant Real Energy Prices Case

Industrialized	4132	8271	14228	43012
Balanced Growth Economies	3176	7410	13390	43225
Primary Exporters	213	343	505	1089
Agricultural Economies	685	1120	1640	3528
Oil Exporters	<u>1586</u>	<u>3610</u>	<u>6551</u>	<u>22249</u>
Total	9792	20754	36314	113103

Source: 1976 consumption data from United Nations Statistical Paper Series J, No. 21, "World Energy Supplies 1972-1976," New York, 1978. Projections are Gordian Associates estimates, based on the methodology described in Appendix A.

EXHIBIT 4. PROJECTED NON-OPEC COMMERCIAL ENERGY CONSUMPTION, BY GEOGRAPHIC REGION*
(Thousands of Barrels of Oil Equivalent Per Day)

Increasing Real Energy Prices Case

	<u>1976</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
Europe, Mideast, N. Africa	2900	6021	7864	15739
Eastern Africa	185	410	459	736
Western Africa	125	209	238	355
E. Asia and Pacific	1027	2121	2678	5096
South Asia	2029	4495	6263	13932
Latin America, Caribbean	<u>3521</u>	<u>7243</u>	<u>9407</u>	<u>18365</u>
Total	9787	20499	26909	54223

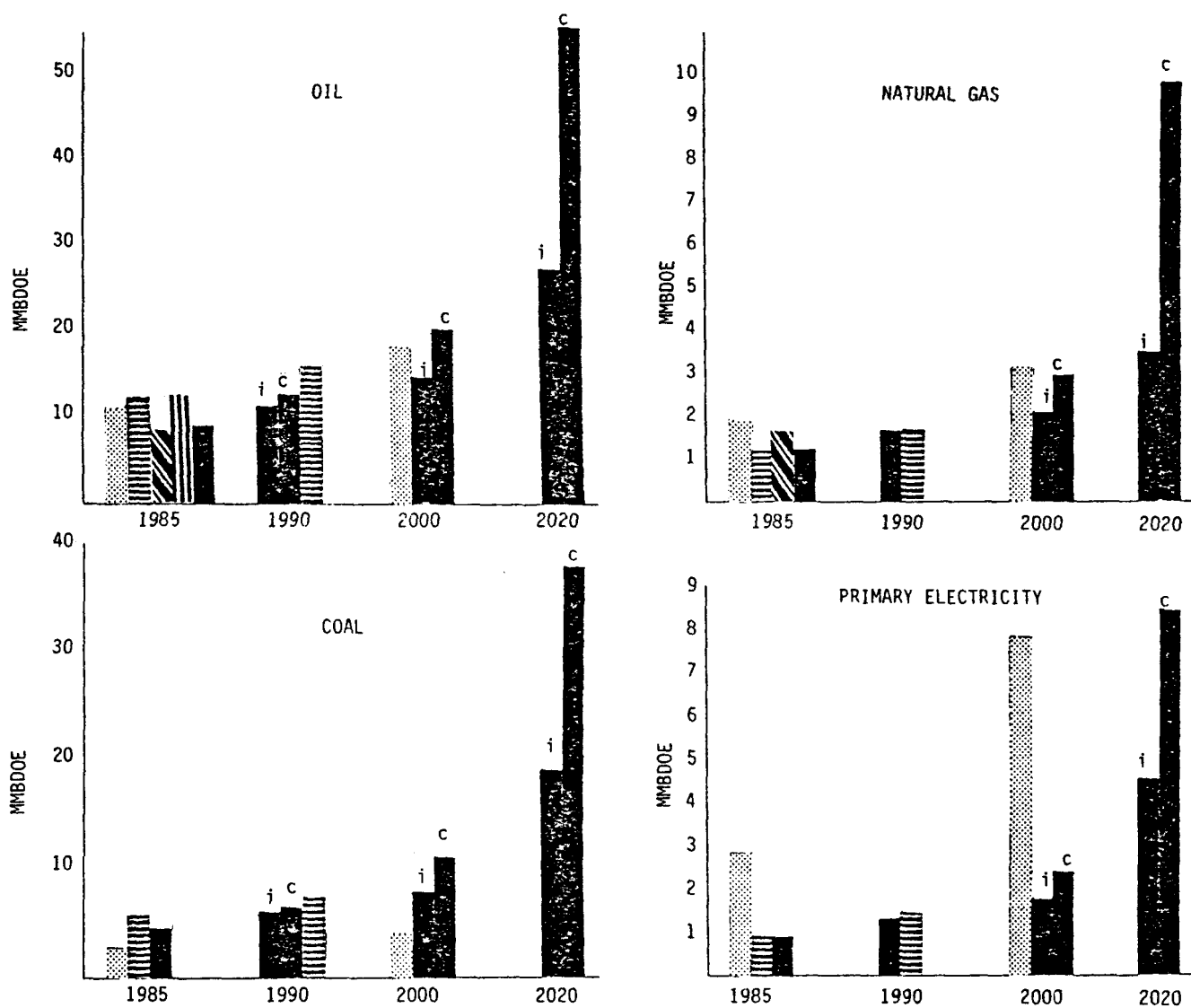
Constant Real Energy Prices Case

Europe, Mideast, N. Africa	2900	6021	9251	22484
Eastern Africa	185	410	540	1051
Western Africa	125	209	279	506
E. Asia and Pacific	1027	2121	3151	7280
South Asia	2029	4495	7368	19904
Latin America, Caribbean	<u>3521</u>	<u>7243</u>	<u>11067</u>	<u>26236</u>
Total	9787	20499	31656	77461

* Projections vary slightly from Exhibit 3 due to difference in base year used for projections.

Source: 1976 consumption data from United Nations Statistical Paper Series J, No. 21, "World Energy Supplies 1972-1976," New York, 1978. Projections are Gordian Associates estimates, based on the methodology described in Appendix A.

EXHIBIT 4a: PROJECTED ENERGY CONSUMPTION IN NON-OPEC DEVELOPING COUNTRIES TO 2020: A COMPARATIVE ANALYSIS



Légend:

WAES

WB

EIA

CIA

GORDIAN

c = constant real energy prices case, i = increasing real energy prices case

EXHIBIT 5. PROJECTED NONCOMMERCIAL ENERGY CONSUMPTION
(Thousands of Barrels of Oil Equivalent Per Day)

	<u>1975</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
Industrialized	1350	1960	2460	3960
Balanced Growth Economies	4040	5880	7415	11760
Primary Exporters	320	445	570	920
Agricultural Countries	2045	3100	3975	6515
Oil Exporters	<u>690</u>	<u>1000</u>	<u>1290</u>	<u>2080</u>
Total	8445	12400	15840	25170

Source: Policy Analysis Division, National Center for Analysis of Energy Systems, Brookhaven National Laboratory, Overseas Development Council, and Gordian Associates.

Supply

In 1975 non-OPEC LDCs produced 7.4 million barrels per day (MMBD) of oil equivalent of primary energy (3.6 MMBD of oil, 2.4 MMBD of coal, 0.9 MMBD of natural gas, and 0.5 MMBD of primary electricity). Exhibit 6 displays the supply for the years 1975, 1990 and 2020 for three world oil reserves addition cases.

Depending on the rate of additions to world oil reserves, the non-OPEC LDC production potential for 1990 is 22.5 to 28.8 MMBD of primary energy (11.3-15.2 MMBD oil, 6.0-6.4 MMBD coal, 3.6-5.9 MMBD natural gas, and 1.7 MMBD of primary electricity -- primarily hydroelectric and nuclear electricity generation). By 2020 our supply projection is 106-138 MMBD of primary energy (34-66 MMBD of oil, 36-35 MMBD of coal, 9-26 MMBD of natural gas, and 11 MMBD of primary electricity). The newly-revised oil projections are based on a detailed analysis of updated LDC production patterns, proved reserves, reserves addition rates, recovery rates, wildcat success rates, regional drilling densities, oil market shifts in crude quality preferences, and government policies. A comparative analysis of Gordian's supply projections in relation to those developed by other organizations (WAES, World Bank, CIA, Energy Information Administration, etc.) is included as Exhibit 6a.

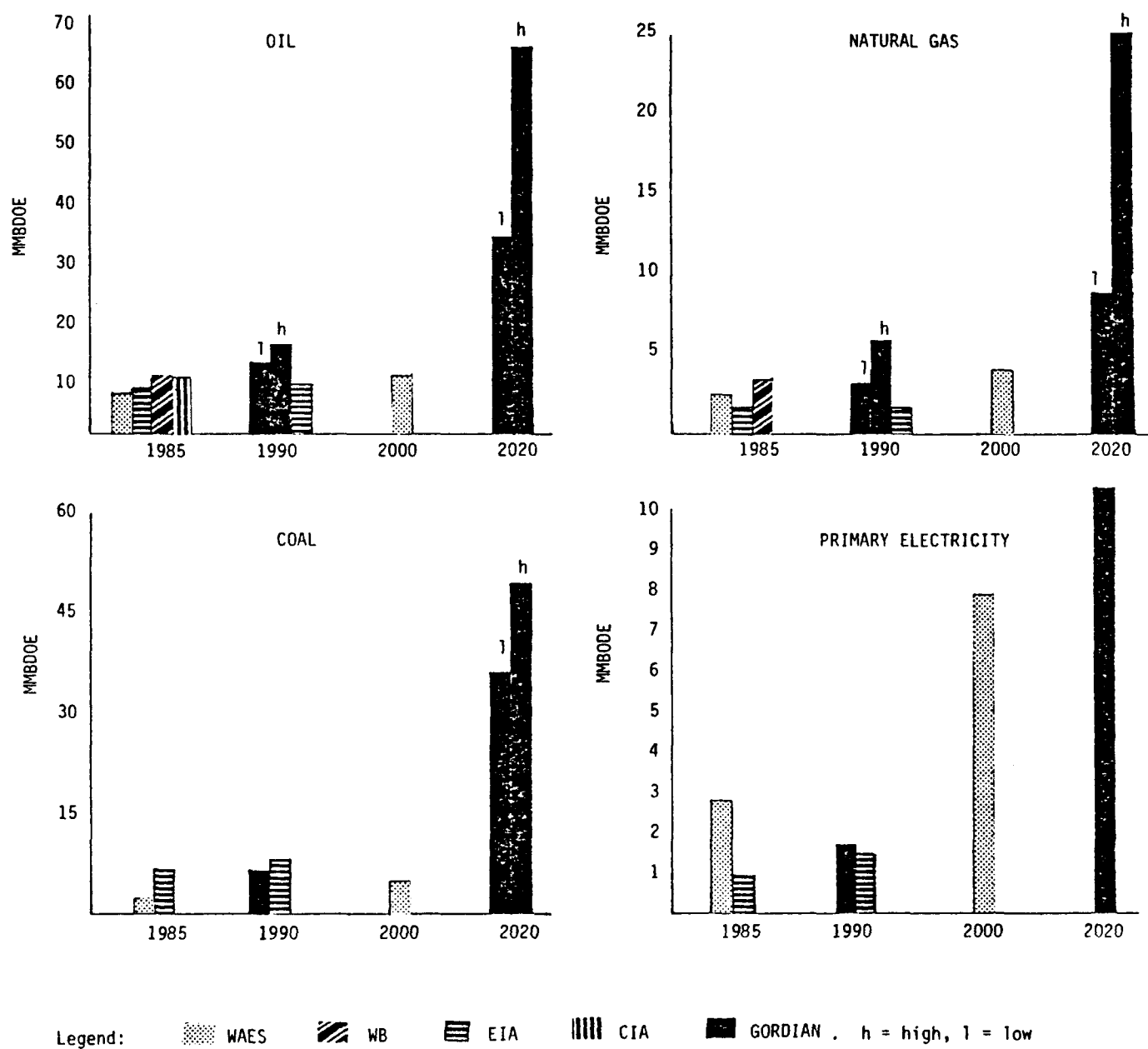
EXHIBIT 6. LDC COMMERCIAL ENERGY SUPPLY TO 1990 AND 2020*
(MMBD Oil Equivalent)

	<u>1976</u>	<u>1990</u>	<u>2020</u>
<u>High Reserves Addition Case</u>			
Oil	3.6	15.2	65.6
Coal	2.4	6.0	36.5
Primary Electricity	0.5	1.7	10.7
Natural Gas	<u>0.9</u>	<u>5.9</u>	<u>25.5</u>
Total	7.4	28.8	138.2
<u>Medium Reserves Addition Case</u>			
Oil	3.6	13.3	48.9
Coal	2.4	6.0	38.7
Primary Electricity	0.5	1.7	10.7
Natural Gas	<u>0.9</u>	<u>4.6</u>	<u>17.1</u>
Total	7.4	25.7	115.4
<u>Low Reserves Addition Case</u>			
Oil	3.6	11.3	33.6
Coal	2.4	6.4	53.0
Primary Electricity	0.5	1.7	10.7
Natural Gas	<u>0.9</u>	<u>3.0</u>	<u>8.8</u>
Total	7.4	22.5	106.1

-
- * High case: 30 billion barrels added per year.
 Medium case: 20 billion barrels added per year.
 Low case: 10 billion barrels added per year.

Estimates of world proved reserves increased from 70 billion barrels in 1950 to 646 billion barrels in January 1978, or an average increase of 8.3% per year. The world recoverable reserves percentage has edged upwards to 35% of oil in place. Developed countries can now recover an estimated 45% of oil in place; estimates of LDC recoverable reserves are currently 25% of oil in place. We expect the transfer of more advanced development technology to LDCs to enable this percentage to increase to 29% in 1985, 38% in 2000, and 45% in 2020. For perspective: each percentage point increase is now the equivalent of two Prudhoe Bays or one North Sea reserves gain.

EXHIBIT 6a. PROJECTED ENERGY PRODUCTION IN NON-OPEC DEVELOPING COUNTRIES TO 2020: A COMPARATIVE ANALYSIS



FINANCING REQUIREMENTS AND PROSPECTS

Even if non-OPEC LDCs were able to achieve energy self-sufficiency as a group, their shortages of capital and foreign exchange could inhibit the development of their resources. Gordian has estimated capital requirements for resource development and then projected capital availability on the basis of fuel type and the economic characteristics of the countries in which the resources are found. The estimated resource development costs are summarized in Exhibit 7.

EXHIBIT 7. ESTIMATED INVESTMENT COST FOR NON-OPEC LDC ENERGY EXPANSION, 1978-2020
(Per Incremental Daily Barrell Equivalents in 1976 Dollars)

Asia/Far East	\$7,900
Oceania	7,600
Central/Southern Africa	5,900
Mexico	5,300
West Indies/Central America	5,000
South America	3,800
Non-OPEC Middle East	3,300
North Africa	3,300

Sources:

Gordian estimates based on data from industry and agency sources, principally: World Energy Conference, 1977 Reports; International Petroleum Encyclopedia 1977; U.N., Petroleum Cooperation Among Developing Countries, 1977; CIA, Major Oil and Gas Fields of the Free World, January 1976 and June 1977; "Petroleum 2000," Oil and Gas Journal, August 1977, 1976-end International Review; API Basic Petroleum Data Book, June 1977; Joint Associations Survey of the U.S. Oil and Gas Producing Industry Annual; "When We'll Start Running Out of Oil," Fortune, October 1977; World Petroleum Report 1976, Maria Palmer Publishing Co., Inc.; World Oil, August 15, 1977 International Outlook Issue; various company annual reports; U.S. Department of Interior, Geological Survey, "Chart of Oil Wells Drilled vs. Size of Areas Favorable for Petroleum," February 1976; Petroleum Intelligence Weekly, various issues; Petroleum Economist, various issues; U.S. ERDA, Market Oriented Program Planning Study (MOPPS), June 1977; U.S. ERDA, LDC Nuclear Power Prospects, 1975-1990; U.S. International Trade Commission, Factors Affecting World Petroleum Prices to 1985; U.S. Department of Interior, Mineral Industry Surveys; American Gas Association, Gas Supply Review; United Nations, World Energy Supplies 1971-1975.

The availability of energy financing for resource exploration and development will vary depending upon the type of energy, the characteristics of an individual LDC, and on other economic factors including domestic savings, international private capital markets, official international development financing, and private companies' equity investment. In general, oil exploration and development can be most readily financed with foreign capital. Natural gas, to the extent that it is associated with oil, should face few financing problems. Coal, hydropower, and non-associated gas will have to be financed predominantly by the LDCs themselves. Based on an analysis of the geographical distribution of reserves, estimates of the aggregate financing shortfall, by fuel type, are presented for the increasing real energy prices case in Exhibit 8.

EXHIBIT 8. ESTIMATES OF AGGREGATE FINANCING SHORTFALL

<u>Fuel Type</u>	<u>Dollar Shortfall</u> (10 ⁹)
Oil	0
Coal	\$31.7
Natural Gas	\$ 7.72
Primary Electricity	<u>\$38.9</u>
Total	\$77.32

Assuming that the storage of indigeneous energy due to the financing shortfall will be made up through oil imports, we estimate that the incremental oil import burden due to inadequate capital to finance indigenous energy development will be \$12.3 billion in 1990 and \$84.5 billion in 2020 for increasing real energy prices case, and only slightly less for the constant real energy prices case. Thus, the additional oil import financing burden is greater than the capital required to finance indigenous energy development.

ALTERNATIVE LDC RESPONSES TO THE ENERGY SITUATION

The energy policy options available to LDC decision-makers are constrained by a range of scarcities which constitute "under-development." Since 1973 energy has become one of the most uniformly acute constraints on a country's economic development, resulting in the need to evaluate all current and potential development paths with regard to their impact on energy consumption.

The effects of energy scarcity on the economic development of LDCs are especially broad based, given that energy is required for virtually all forms of production and distribution, and that increased energy consumption is therefore correlated with higher GNP, modernizing, and structural change. Finally,

the failure to set and meet energy conservation targets increases the reliance on imported fuels and may lead to serious financial and balance of payments problems with far-ranging economic repercussions.

A number of alternatives are available to LDCs desiring to maintain or improve their growth rates, to improve the distribution of the benefits of such growth, or to accomplish other social or economic objectives within the constraints imposed by the quadrupling of oil prices since 1973. These options include:

- . energy conservation within the major energy consuming sectors,
- . intersectoral shifts in investment and growth in order to emphasize less energy-consumptive sectors,
- . more intensive development of traditional, indigenous commercial or non-commercial energy resources,
- . development and/or adoption of new energy supply technologies for renewable energy sources,
- . limitations on domestic consumption (to maintain previous rates of domestic savings) and/or imports (to preserve foreign exchange),
- . generation of more exports and therefore more foreign exchange to pay for the increased cost of energy imports,
- . more equitable distribution of the benefits of whatever growth level is achieved, in order to assure that everyone realizes at least some basic level of human well-being, and
- . greater regional LDC energy and/or economic cooperation.

The potential responses to energy scarcities can be classified into two broad categories: energy conservation and fuel switching, and the intensified development of renewable energy.

The potential for energy conservation and fuel switching varies widely by sector and activity. For example, certain industrial and transportation activities present relatively intractable technical obstacles to energy conservation. Nevertheless, their importance to economic development suggests that they will continue to have high priority in LDCs. On the other hand, in agricultural and rural areas, social and economic obstacles may serve to impede the implementation of technically feasible solutions for energy conservation (the solutions would be primarily based on renewable resources such as solar, biogas, wind, etc.).

The renewable energy sources which merit particular attention include fuelwood, biogasification, and solar energy.

- . Fuelwood is the most commonly used renewable energy source in LDCs. However, rapid forest depletion and the increasing demand for fuelwood require new strategies using scientific forestry methods such as fuelwood plantations, "timber stand improvements," and the development of secondary forest fuels through carbonization, distillation, and gasification.
- . Biogasification is potentially the most attractive energy source in rural areas. It uses organic wastes in a manner that does not compete with, and may even enhance, food production. It is well suited to small-scale uses. Several workable units have been designed in India and the People's Republic of China; in the People's Republic alone, some 17 million families already rely on biogas for cooking and lighting.
- . Solar energy can be provided through two principal means: solar collection systems and photovoltaic systems. While both are potentially valuable energy technologies, high production costs currently inhibit their widespread application.

LIKELY RANGES OF RESPONSE BY LDC COUNTRY GROUPS

Even if non-OPEC LDCs achieve energy self-sufficiency as a group, numerous countries will face serious energy shortages because their resources are unevenly distributed. For this reason, and also because their economic structures differ widely, a broad range of responses to the energy situation can be anticipated. While all generalizations as to country responses are hazardous, we have identified the salient characteristics, by country group, that are likely to mold their energy policies. The five country groups, as defined earlier, are: industrialized countries, balanced growth economies, primary exporters, agriculturally oriented countries, and current oil exporters.

Industrialized Countries

As a group, these nine LDCs are more heavily industrialized, have higher per capita incomes, are more urbanized, and have more developed socio-economic infrastructures than the other four groups. Industrial activity accounts for a higher contribution to GDP than agricultural activity, with relatively less traditional handicraft production and relatively more "modern industry" than other LDCs. They also consume more energy per capita than any other LDC group. Their heavy capital commitments to industrialization give these nations a vested interest in their currently energy intensive development paths. Their high growth rates will likely receive greater emphasis than energy conservation.

Therefore, the industrialized LDCs can generally be expected to respond to the energy situation by: (1) effecting such energy conservation as is possible without endangering their continued industrial development, and (2) by expanding their exports to finance their energy import requirements, and by developing their indigenous resources, or both.

Balanced Growth Countries

The eight countries within this category have diverse and relatively substantial resources bases, but do not yet have an infrastructure so specialized as to commit them to a particular development course. Most have already completed their primary and intermediate phases of import substitution, and are attempting (often successfully) to embark upon the final stage of becoming self-sufficient in the heavy industrial sector. At this point, all of the countries in this group primarily rely on the agricultural sector to provide for the economic and social well-being of their populations. This category is unique among LDC groups in that it has considerable flexibility to choose future development strategies.

In principle, the great differences in sectoral energy intensities give balanced growth economies substantial scope for energy conservation through intersectoral production shifts. However, this flexibility may be illusory, insofar as it depends upon major social, economic, and organizational changes that would be very difficult to implement.

Primary Exporters

With regard to their energy policy options, the eleven exporters of primary products are, in some respects, in a situation similar to that of the industrialized LDCs: they are limited in their ability to institute intersectoral shifts in economic activity by the fact that a single sector -- mining -- provides their principal resource for economic development. Sixty to eighty percent of the minerals produced in these countries are exported; therefore, their exports as a percentage of GNP are higher than for other LDCs.

The equipment used in mining is energy-intensive, and is based on imported technologies. The exploitation and distribution of mineral resources also require highly developed transportation networks to bring large volumes of minerals to ports from which they are exported to international markets.

Unlike the case of industrialized LDCs, however, the sector to which these countries are committed is not capable of expanding to the point of employing a significant share of the labor force. In fact, the development of primary exporting countries usually involves an attempt at economic diversification. As they are not yet committed to any specific form of diversification, they are more capable of reordering their economic priorities outside the mining sector, in response to energy bottlenecks.

Agriculturally Oriented Economies

These 39 countries can be divided into subgroups based on the character of their economies and the classification of some 20% of these nations as exporters of agricultural commodities. The structural economic characteristics of all of these nations reflect their limited level of development and a continuing tie to traditional or subsistence levels of production. Most of their land area is under shifting or marginal cultivation; hunting, gathering, and primitive cultivation are also prevalent, while nomadic herding and the cultivation of plantation crops is practiced in isolated areas. The countries in this category are uniformly without significant commercial quantities of mineral resources. Non-commercial fuels account for the bulk of their energy consumption.

The agriculturally oriented economies are likely to face more severe energy financing problems than any other LDC group. Because of their narrow resource base, they have a limited range of solutions to energy scarcity, and have suffered grave economic consequences during the energy crisis. Their most viable options are likely to lie in an attempt to increase their agricultural productivity through land- and labor-intensive techniques. Their energy needs response will depend upon the application of small scale technologies to agriculture, and on environmental policies that protect and enhance their available renewable energy resources, such as reforestation and fuelwood plantations. These solutions can be consistent with improvements in rural lifestyles and productivity. In general, agriculturally oriented LDCs will require substantial public assistance (bilateral and multilateral) to cope successfully with integrated energy/developmental problems.

Current Oil Exporters

The nine LDCs that export oil and are not members of OPEC are included in this group. This category is expected to grow as the rate of exploration accelerates throughout the world and particularly in LDCs.

Oil exporters are likely to respond to higher energy prices more through supply increases than through energy conservation. They are the least likely to conserve energy or alter their development strategies in order to conserve energy. As a group, they are likely to press for higher oil prices, perhaps even more than the OPEC nations, because they need developmental revenues but lack the huge revenue surpluses characteristic of OPEC members.

The rate of resource development in oil exporting LDCs will depend upon a number of interrelated factors. Principally, their developmental revenue needs must be compared with the trade-offs between increased oil production now and higher energy prices in the future.

1. NATURE OF THE PROBLEM

1.1 CHARACTERISTICS OF NON-OPEC LDCs

While the primary measure used to identify LDCs (low GNP) has been cited in the Executive Summary, other socio-economic factors are also common to this group of countries. While it is dangerous to generalize across all of the 87 nations listed in Exhibit 9, we offer the following as important prevalent characteristics of most LDCs:

Relative and Absolute Poverty. Income distribution varies widely among LDCs, although most evidence suggests that they have a greater disparity in their relative income distribution than developed countries.* However, because of the LDCs' substantially lower average income per capita, in virtually all cases a greater proportion of their population is below the "poverty line" as defined by the LDCs themselves -- even after taking into account rural subsistence production and other income not counted in GNP. Using World Bank definitions, one-third of the LDCs' total population, and almost three-fourths of the population of Asian countries is in "absolute poverty" (below \$50 per capita income per year).** One result is the tragic incidence of malnutrition and the death by starvation of an estimated fifteen million people in LDCs each year.

"Dual Economy" and Predominance of Pre-Industrial Sectors. Although there is substantial variation among LDCs, the primary or the pre-industrial sector, particularly for the lowest GNP countries, generally accounts for the largest share of national income and engages the vast majority of the economically active population. Industrial activity is not only extremely limited (sometimes employing less than one percent of the labor force, as in Niger and Chad), but much of it consists of traditional handicraft production. The tertiary (services) sector typically includes a large percentage of low-productivity domestics, street hawkers, itinerant merchants, etc. Where it exists, the "modern industrial" sector (and, in many cases, the primary exports sector) is often virtually independent of the "traditional" sectors. This duality is particularly pronounced in less industrialized LDCs and even exists to some extent in such relatively industrialized LDCs as Brazil or Mexico.

* See, for example, Montek S. Ahluwalia, "Inequality, Poverty, and Development." Journal of Development Economics, March 1976, pp. 307-42.

** World Bank, "Rural Development," February 1975, and Hollis B. Cherney et. al., Redistribution with Growth. London: Oxford University Press, 1974.

EXHIBIT 9. NON-OPEC LDCs' PER CAPITA GNP

High (\$500 - Above)	Medium (\$200 - \$500)	Low (Less Than \$200)
*E Angola	E Bolivia	Afghanistan
Argentina	Botswana	Bangladesh
Brazil	Cameroon	Benin
Brunei	Central African Empire	Burma
Chile	Comoros	Burundi
Colombia	E People's Republic of Congo	Chad
Costa Rica	E Egypt	Ethiopia
Cyprus	El Salvador	Gambia
Dominican Republic	Eq. Guinea	Guinea
Fiji	Ghana	Haiti
Greece	Honduras	India
Guatemala	Ivory Coast	Lesotho
Guyana	Jordan	Madagascar
Jamaica	Kenya	Malawi
Republic of Korea	Liberia	Mali
Lebanon	Mauritania	Nepal
Malaysia	Morocco	Niger
Mauritius	Mozambique	Pakistan
E Mexico	Papua New Guinea	Rwanda
Nicaragua	Philippines	Sierra Leone
E Oman	Senegal	Somalia
Panama	Swaziland	Sri Lanka
Paraguay	Sudan	Tanzania
Peru	Thailand	Upper Volta
Singapore	Togo	Zaire
Spain	Uganda	
Surinam	Yemen Arab Republic	
E Syrian Arab Republic		
Taiwan		
Trinidad/Tobago		
E Tunisia		
Turkey		
Uruguay		
Yugoslavia		
Zambia		

Source: World Bank World Atlas 1976 (excluding most Communist countries, countries with GNP per capita greater than \$2800, and countries with populations below 250,000). "High," "medium," and "low" categories are based on World Atlas 1976 per capita GNP levels.

* E = net oil exporter, based on UN World Energy Supplies 1971-75.

Inadequate Physical and Social Infrastructure. Compared to developed countries, most LDCs have low literacy rates, limited medical facilities, a high incidence of disease and malnutrition, and high death rates, especially infant mortality. Except in a few countries, old age insurance, food subsidies, or other forms of income redistribution are insignificant. Agriculture-related services, such as extension services of agricultural credit institutions, are nonexistent in many LDCs. The physical infrastructure, including transportation, communications, power and sanitary services, is generally inadequate. At the same time, rapid population growth, and more critically, urban population growth, has severely strained the existing infrastructure and social services. The inability to cope with rapid urbanization (which will result in a number of LDC urban centers with populations of over ten million each by 1990) already threatens the social structures of many LDCs.

Population and GNP Growth. Most LDCs have birth rates three to four times those of developed countries, leading to high population growth rates.* Thus, growth in GNP per capita, which presumably overstates actual LDC growth,** has not been enough to narrow the income gap between the lower income LDCs and the industrialized countries. The experience of those few LDCs who have substantially lowered their population growth rates suggests that this can be achieved only after a minimum of "basic human needs" have been met.

Dependence on External Capital and Trade. The low absolute levels of LDCs economic activity, coupled with this activity's low level of monetization, have meant that even with domestic rates of monetary savings near those for industrialized countries,*** absolute levels of domestic capital accumulation are

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- * There is substantial evidence that high birth rates are due at least in part to high infant/childhood mortality rates. Poor parents, valuing children not only as their offspring but also partly as both sources of energy (in a setting where only human or perhaps animal energy is available to them) and generally their only form of "old age insurance," feel impelled to bear many children to ensure that at least one or two survive.
 - ** Since most of the traditional subsistence sector and many "urban informal" sector activities are not included in GNP accounting, any net immigration of people from these sectors to the "modern" sector, even with no net gain in output, will register as a gain in GNP. As shown later, the extent of this migration is quite substantial.
 - *** 1976 non-OPEC LDC national savings were 19.1% of GNP (23.9% for upper middle, 18.4% for intermediate middle, 17.9% for lower middle, and 11.0% for low income LDCs) versus 20.3% for industrialized countries (World Bank "World Economic and Social Indicators," August 1977).

insufficient to support the levels of investment in infrastructure and productive assets necessary to create self-sustaining development. Also, because of wide income disparities and purchasing power concentrated in a small fraction of the population, the internal market of even such large LDCs as India may be too small to support the domestic industry and market agriculture necessary for self-sustaining development. At the same time, almost all LDCs must import consumer goods (both necessities and luxuries), capital goods, and increasingly, basic food-grains. Thus, most LDCs are heavily dependent on foreign currency flows (export earnings, private debt or equity capital) and/or official foreign financial assistance. Yet, most LDCs have either very little short-run export potential (especially in many African countries) or two or three primary commodities which account for the bulk of their export earnings. Except for recent oil prices, primary export prices have been unstable and beyond the exporter's control. Private debt capital has been available only to a handful of countries,* and there are signs of increasingly stringent policies regarding private lending to LDCs. Finally, official financial assistance generally is not adjusted to offset changes in LDCs' export earnings potential. The net result of these constraints is that non-oil exporting LDCs generally depend on capital flows, which they can neither control nor accurately predict, for many of their basic consumption necessities and for needed investment. Exhibit 10 highlights some of these aspects of "underdevelopment."

1.1 PRESENT LDC ENERGY AND FINANCIAL POSITION

In 1975 the 76 non-oil exporting LDCs imported approximately 2.7 million barrels of oil per day, while the 11 non-OPEC oil exporters exported approximately 1.1 million barrels per day. At an assumed average delivered price of \$13 per barrel, the oil-importing LDCs together spend almost \$13 billion (U.S.) on oil imports, representing approximately 7% of their total import value.

Concurrently, these LDCs have been investing heavily in indigenous energy production and processing capacity -- an average of \$4.2 billion per year over the period 1960-74 -- with the largest share devoted to the expansion of electric power generation and distribution systems. Over the last decade investment for electric power expansion has averaged 7-8% of the LDCs gross fixed capital formation.** These investment levels can be related to average

* In 1976 just five countries -- Brazil, Mexico, the Philippines, Argentina, and the Republic of Korea -- accounted for over 70% of all Eurocurrency bank credits. The first three accounted for just under 70% of publicly announced bond issues. (From Morgan Guaranty Trust Company, World Financial Markets," July 1977.)

** Efrain Friedmann, "Financing Energy in Developing Countries," World Bank Reprint Series No. 27, March 1976.

EXHIBIT 10. NON-OPEC LDCs' SOCIAL INDICATORS*

	Upper Middle Income LDCs	Inter Middle Income LDCs	Lower Middle Income LDCs	Low Income LDCs	Industrialized Countries
GNP per capita (current U.S. \$)	1,558.2	705.6	365.5	142.7	4,827.5
Pop. growth rate (%) total	1.5	2.7	2.6	2.5	0.8
Pop. growth rate (%) urban	2.9	5.0	4.5	4.7	1.4
Urban % of population-1960	43.1	36.3	21.3	12.4	66.7
-1973-1975	53.7	50.4	24.0	16.4	74.6
% of labor force in agricul- ture					
1960	49.2	59.1	66.2	67.3	20.8
1973-1975	32.8	43.8	60.6	69.5	10.4
Life expectancy at birth -					
1960	60.4	51.5	44.8	38.6	69.5
1973-1975	63.4	60.1	52.8	45.7	72.4
Population per physician	1,186	2,138	5,282	12,679	635
-hospital bed	161	476	702	1,325	93
Per capita per day supply of calories (% of requirement)-					
1960	108.7	98.5	89.2	89.1	115.2
1973-1975	118.0	106.3	91.9	96.0	112.0
Protein (grams) per capita	92.0	60.9	50.0	62.9	95.0
Adult literacy rate (%)	87.4	72.5	63.0	42.5	99.0
Average commercial energy (kg. coal/yr. per capita)	2,006.6	611.9	269.4	94.3	4,681

* All data are "most recent estimates" (1973-1975) except where otherwise noted.

Source: World Bank, "World Economic and Social Indicators," August 1977, Table X.
Sources are explained in notes accompanying Table X.

increases in non-OPEC LDC production over the same period of 6.3% for oil, 11.2% for natural gas, 1.6% for coal, and 6.3% for electric power generation capacity.*

Since the 1973 increase in world oil prices, non-oil exporting LDCs have run large balance of payments (current account) deficits, have seen their terms of trade deteriorate (from an index of 100 in 1970 to 87 in 1976), and have incurred large new debts. As a consequence of increased private credit at substantially higher interest rates,** 1976 debt service for these 76 LDCs has risen to 10% of their total export value (Exhibit 11). For 1977 debt service represents over 20% of the total export value for nine large LDCs and at least 10% for another ten large LDCs.*** As a result of this situation, increased oil prices, and other factors such as the post-1974 recession in industrialized countries, there has been a marked slowdown in LDC economic growth rates.

Recently, such measures as the Comptroller of the Currency's limitation on U.S. banks' loans to individual LDCs suggest a tightening of private credit. At the same time, although official flows have increased somewhat (primarily with the addition of the IMG "Witteveen Facility") the terms imposed (particularly by the IMF, which has generally required that recipient countries take traditional deflationary measures to cut back consumption, imports, and inflation) indicate that while such lending may avert short-term defaults on other international loans, providing for the minimum needs of all the world's people will be even further delayed.

1.3 CONCERNS ABOUT THE FUTURE

A number of concerns have been expressed by various groups regarding the future energy position of the LDCs. Among these concerns are:

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- * Adrian Lambertini, "Energy Prospects in OECD Countries and Possible Demand for OPEC Oil Exports to 1980." World Bank Staff Paper No. 221, Sept. 1975. Absolute production increases over the period were 1.2 million barrels per day for oil, 570.5 million cubic feet for natural gas, 8.5 million metric tons for coal, and almost 20 million megawatts for electric power generating capacity.
 - ** UNCTAD, "World Economic Outlook 1977-78," February 25, 1977. Includes only countries with accumulated debts of at least \$500 million as of the end of 1975. The nine countries with debt service representing over 20% of total export value are: Argentina (23%), Brazil (53%), Chile (37%), Egypt (30%), Mexico (43%), Pakistan (34%), Peru (28%), Uruguay (31%), and Zaire (42%).
 - *** From 1973-1976 total official flows fell from 57-44% of total commitments, while total private flows increased from 43-56%. (World Bank, "World Debt Tables," September 1977, and World Bank, "World Economic and Social Indicators," August 1977).

- While striving to meet at least the minimum needs of their populations, the LDCs as a group may well deplete both their commercial and noncommercial indigenous energy sources. If not constrained financially, the LDCs will become a much larger net consumer of world energy (particularly hydrocarbons), thus hastening the period of absolute hydrocarbon shortages and/or substantial increases in world hydrocarbon prices.
- Both providing for human needs and averting a worldwide energy shortage will require (on the part of both developing and developed countries) the discovery of new, commercially exploitable traditional energy supplies, technological breakthroughs allowing the broad use of solar or other widely available "new" energy sources, changes to less energy intensive economic growth policies, or some combination of these.

EXHIBIT 11. RELATIONSHIP OF PUBLIC DEBT AND DEBT SERVICE TO GNP AND EXPORTS
FOR 76 NON-OIL EXPORTING DEVELOPING COUNTRIES

		<u>Percent</u>			
	<u>1967-1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>
Debt to GNP		11.9	11.9	13.4	15.0
Debt to Exports		76.5	71.1	85.0	88.9
Debt Service to Exports		10.1	8.4	9.9	10.0
Annual GNP Growth Rates	6.1	6.7	5.2	3.4	5.1

- For most oil importing LDCs, the combination of oil import payments and debt service payments will reduce their ability to finance the investment necessary to stimulate economic growth or to provide for the minimum basic human needs of their populations.
- Because of the underlying disparity in income and wealth both between developing and developed countries and within most developing countries themselves, sufficient energy will not be made available to a large portion of the world's population -- just as food, health and education services, etc., are not available to them. Thus, even a solar energy or other breakthrough will do little to solve the problems of starvation, extreme poverty, and intense human suffering in the world.

In addressing these and other considerations of the LDCs energy position, we have, of necessity, used statistics liberally. Before proceeding, it is essential that we make two points:

- Because of the wide intercountry variations in definitions and data collection methods, even the current information on LDCs is extremely poor, giving at best a general indication of their status and trends. This problem is compounded when making projections. Thus, the "scenarios" presented here should be considered as hypothetical, intended only to answer basic "what if..." questions.
- In reviewing statistics and aggregate country or regional information, one tends to lose sight of the basic humanity -- the sanctity -- of the tens of million of individuals that cannot even have the reasonable assurance that they or their children will survive another day, week, month, or year.

2. PROJECTION OF LDC ENERGY DEMAND AND SUPPLY TO 2020

To provide a basis for consideration of the long-term impacts of the projected world-wide energy situation on LDCs, historical trends in LDC energy consumption have been projected to the year 2020. This potential demand, presented in an "increasing real energy prices case" and a "constant real energy prices case," was compared with a range of possible actions for LDC resource development.

The demand projections in this chapter are divided into two categories: commercial primary energy and noncommercial energy. Commercial energy demand has been analyzed in terms of two scenarios. The "increasing real energy prices case" assumes GNP growth rates which are lower than recent historical trends, and also builds in a response to real energy price increases in the years 1990 and 2020. A price elasticity of 0.3 is assumed for this case. The "constant real energy prices case" uses extrapolation to 2020 of the population and GNP growth rates which the World Bank developed for the period 1980-1985. Only minor adjustments were made in the historical income elasticities. Therefore, this case reflects the more optimistic of the two assumptions, and fails to take into account the energy scarcity that would result if these trends continued unabated for the next 40 years. Specifically, such scarcity could, through a feedback effect, lead to reductions in real GNP growth, and to price increases -- neither of which are assumed in this case. The "constant case" should thus be viewed only as a scenario which underscores the unviability of continuing present trends. It may be regarded as plausible but optimistic through 1990, and purely hypothetical thereafter.*

Both cases utilize the same demand elasticities, as discussed in Section 2.1.1. Noncommercial energy demand has been estimated for these 87 countries, as detailed in Section 2.1.2. Finally, all projections of demand and supply in this report are made in terms of the five country categories delineated in the Executive Summary. These categories were developed by Gordian Associates on the basis of similar efforts by Hollis Chenery of the World Bank, and are discussed in more detail in Chapter 5.

2.1 PROJECTIONS OF LDC ENERGY DEMAND TO 2020

Gordian has estimated the demand for "commercial primary energy" -- oil, natural gas, primary electricity (hydropower, nuclear, and a small amount of

* Although it could, of course, be realized under extremely favorable supply conditions.

geothermal), and coal -- for each LDC country group to the year 2020. Crude estimates on noncommercial energy demand, developed jointly by Gordian Associates, Brookhaven National Laboratory and the Overseas Development Council are also contained in this section.

2.1.1. LDC Demand for Commercial Primary Energy

Increasing Real Energy Prices Case. For each of the LDC country groups, our projections assume a slight reduction in both current trends of economic growth and the relationship between that growth and energy consumption. The assumptions used for this are summarized in Exhibits 12 and 13. In general, these estimates rely on World Bank and UN projections of annual growth rates in GNP and on observed historical relationships between developing countries' GNP growth rates and their growth in demand for commercial energy ("crude income elasticity of demand for commercial energy"). In order to obtain a more accurate projection of oil demand, it was assumed that there would be a large unsatisfied demand for coal, natural gas and other fuels, which will result in an increased demand for oil. Using projection methods which take coal and natural gas supply constraints into account, the resultant extrapolations are not, strictly speaking, projections of "unconstrained demand." However, Gordian's projections of energy consumption closely parallel studies by the World Bank and others, both in methodology and, at least for the period through 1990, in results. The underlying assumptions and methodology used by Gordian and others (including the World Bank, United Nations, and "WAES") are presented as Appendix A.

EXHIBIT 12. LDC COMMERCIAL ENERGY CONSUMPTION ASSUMPTIONS FOR ANNUAL GNP GROWTH RATE* -- INCREASING REAL ENERGY PRICES CASE

	<u>1975-1990</u>	<u>1990-2020</u>
Industrialized Countries	5.5%	4.4%
Balanced Growth Economies	5.5	4.4
Primary Exporters	3.6	2.8
Agricultural Countries	3.6	2.8
Current Oil Exporters	6.3	5.4

* Source: WAES (Reference 14), based on average of WAES high and low estimates extrapolated to 2020.

EXHIBIT 13. LDC COMMERCIAL ENERGY CONSUMPTION ASSUMPTIONS FOR INCOME
ELASTICITIES OF DEMAND BY TYPE OF COMMERCIAL ENERGY*--
INCREASING REAL ENERGY PRICES CASE**

	<u>Industrialized Countries</u>	<u>Balanced Growth Economies</u>	<u>Primary Exporters</u>	<u>Agricultural Countries</u>	<u>Current Oil Exporters</u>
<u>Oil</u>					
1957-77	.88	1.1	1.1	.85	.88
1977-90	.85	1.04	1.04	.90	.85
1990-2020	.82	.98	.98	.96	.82
<u>Electricity</u>					
1975-77	1.15	1.6	1.6	1.8	1.15
1977-90	1.09	1.52	1.52	1.7	1.09
1990-2020	1.03	1.43	1.43	1.6	1.03
<u>Natural Gas</u>					
1975-77	1.0	1.2	1.2	1.0	1.0
1977-90	.97	1.17	1.17	1.03	.97
1990-2020	.94	1.13	1.13	1.06	.94
<u>Coal</u>					
1975-77	.94	.88	.88	1.45	.94
1977-90	1.12	.98	.98	1.57	1.12
1990-2020	1.13	1.08	1.08	1.68	1.3

Price Elasticity of Demand for Total Commercial Energy:***

All country groups: 0.3

* The same assumptions, with the exception of the price elasticity, also apply to the "constant real energy prices case."

** Gordian Associates Inc., based on World Bank elasticity estimates for oil and gas and World Bank staff estimates for coal and primary electricity.

*** Based on World Bank, Energy Prospects in Non-OPEC Developing Countries, First Draft, August 1978.

It is most important to note the following assumptions used in the formation of our projections:

- . Only minor changes to 2020 will occur in historical income elasticities of LDC demand for commercial primary energy.
- . Energy prices will increase in real terms by 50% by 1990 and 100% by 2000. A price elasticity of demand (the ratio of the percentage change in energy demand to the percentage change in energy price) of -0.3 was used to reduce total commercial energy demand in future reference years.

These assumptions are conservative in a number of ways, leading to a low estimate of future LDC energy demand. Further, the income elasticities that we have used are on the low side compared to those of Leontief, the World Bank and other recent estimates. Finally, we have applied a generous price elasticity of demand.

Each commercial primary energy source is addressed briefly below:

- . Oil. Based on the forecasts described above, the demand for oil by the oil importing LDCs will increase by 380%, reaching over 21 million barrels per day in 2020; while demand by all LDCs (including present non-OPEC oil exporters) will increase by 411% to nearly 28 million barrels per day in 2020.
- . Natural Gas. Based on the same methodology, 2020 natural gas demand by oil importing LDCs is projected to increase 553%; and demand by all LDCs, 428%. This forecast, which may appear low in view of the relative abundance of natural gas reserves, reflects the past limitations on natural gas consumption (and therefore lower income elasticities of demand for natural gas) due to the high cost of transporting it by pipeline or by ship as LNG where reserves are located far from population and industrial centers. Substantially higher natural gas demand projections, using an alternative methodology which places less weight on the impact of past supply/transportation constraints, are presented in Appendix A.
- . Primary Electricity. The general estimation methodology yields substantially higher growth rates for primary electricity -- hydropower, nuclear, geothermal and solar -- reflecting the fact that electric power (both from primary and fossil fuel plants) has generally captured an increasing share of total LDC energy demand in recent years. This trend is projected to continue, particularly for low and middle income LDCs in Africa and Asia, where electrification even of their middle income countries and major urban areas is still in relatively early stages. At the same time, fossil fuel fired thermal energy is projected to account for a declining share of total electric power. The LDC demand for primary electricity is projected to increase by 808% from 1975 to 2020 for oil importing LDCs, and by 824% for all LDCs. An alternative estimation methodology yielding even greater increases is presented in Appendix A.

- . Coal. In this case, Gordian used a different methodology which reflects supply constraints as well as potential demand. With these assumptions, coal consumption (as opposed to "potential demand" for coal) increases by 633% from 1975 to 2020 for oil importing LDCs, and by 660% for all LDCs.
- . Other Commercial Energy. As an extrapolation of the "status quo," this scenario does not address likely 2020 LDC demand for solar, hydrogen, or other "emerging" energy sources which did not contribute significant amounts of energy in 1975, except to the extent that they may be included as primary electricity. These are treated in the next section, as well as in the alternative supply-demand scenario presented in Chapter 3.

Summarizing the projections for these commercial primary energy sources yields a non-OPEC LDC demand for all commercial primary energy of 55 MMBDOE in 2020 (Exhibit 14). The implied average annual growth rate in LDC demand for a primary commercial energy is 4.07% per year, somewhat lower than the growth rate projected by the World Bank (see footnote to Exhibit 14).

Of more importance than the increase in overall energy demand is the implication that if all projected demands were to be satisfied for each energy source in 2020, oil would account for 51% of all LDC primary energy, versus a 60% share in 1975. However, the use of oil by LDCs would have increased more than five-fold, to a level exceeding the late 1977 world oil production rate. This would occur despite tremendous increases in consumption: therefore, the production of energy from other conventional commercial sources also increases. In short, the dramatic rise in the demand for oil will not result from a lack of development of alternative conventional energy sources.

Constant Real Energy Prices Case. This case assumes:

- . a continuation to 2020 of estimated LDC population and GNP growth rates which the World Bank intended to be used only to 1985,
- . only minor changes to 2020 in historical LDC income elasticities of demand for commercial primary energy, and
- . no increases in real energy prices (i.e. the price of energy relative to all other goods and services) through 2020.

These presume no dramatic changes in the way the world will function over the next 45 years. This is patently absurd, judging by the events of the 45 years prior to the 1976 base year: the Great Depression, World War II and succeeding years, the emergence of the People's Republic of China as a world power, the decline of colonialism, quantum advances in transportation and communication, and the birth of most of the countries addressed in this report.

The GNP growth assumptions of this case are shown in Exhibit 15. The income elasticity assumptions are the same as in the "increasing real energy prices

EXHIBIT 14. PROJECTED COMMERCIAL ENERGY CONSUMPTION FOR NON-OPEC LDCs --
INCREASING REAL ENERGY PRICES CASE
(Thousands of Barrels of Oil Equivalent Per Day)

<u>Country Category</u>							
<u>Industrialized Countries</u>	<u>1976</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000*</u>	<u>2010*</u>	<u>2020*</u>
Oil	2802	3107	3918	4940	6051	8720	11323
Coal	857	1041	1399	1890	2716	4616	7068
Primary Electricity	228	326	435	581	767	1192	1659
Natural Gas	<u>245</u>	<u>288</u>	<u>374</u>	<u>485</u>	<u>621</u>	<u>935</u>	<u>1268</u>
Total	4132	4762	6126	7886	10155	15463	21328
<u>Balanced Growth Economies</u>							
Oil	1363	1716	2264	2987	3878	5923	8150
Coal	1557	2012	2629	3420	4596	7266	10351
Primary Electricity	115	220	323	474	713	1264	2015
Natural Gas	<u>141</u>	<u>194</u>	<u>264</u>	<u>359</u>	<u>491</u>	<u>789</u>	<u>1143</u>
Total	3176	4151	5480	7240	9678	15242	21659
<u>Primary Exporters</u>							
Oil	169	176	211	253	282	370	437
Coal	24	33	39	46	53	71	86
Primary Electricity	19	21	27	35	43	62	82
Natural Gas	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
Total	213	231	278	335	379	504	606
<u>Agricultural Countries</u>							
Oil	611	674	791	928	1030	1344	1581
Coal	22	26	34	44	57	87	120
Primary Electricity	37	39	52	69	89	134	182
Natural Gas	<u>15</u>	<u>13</u>	<u>16</u>	<u>19</u>	<u>22</u>	<u>29</u>	<u>35</u>
Total	685	752	893	1060	1198	1594	1918
<u>Current Oil Exporters</u>							
Oil	1128	1284	1674	2182	2907	4557	6436
Coal	92	140	196	274	442	840	1438
Primary Electricity	45	84	117	162	236	404	623
Natural Gas	<u>321</u>	<u>397</u>	<u>534</u>	<u>719</u>	<u>1009</u>	<u>1665</u>	<u>1087</u>
Total	1586	1905	2521	3337	4594	7466	9584
<u>All Countries</u>							
Oil	6070	6957	8858	11290	14148	20914	27927
Coal	2552	3261	4297	5664	7864	12880	19063
Primary Electricity	444	690	954	1321	1848	3056	4571
Natural Gas	<u>723</u>	<u>893</u>	<u>1189</u>	<u>1583</u>	<u>2144</u>	<u>3419</u>	<u>3534</u>
Total	9789	11801	15298	19858	26004	40269	55095

* Adjusted for real price increases.

Source: 1976 consumption data from United Nations Statistical Paper Series J. No. 21. World Energy Supplies 1972-1976. New York 1976. Projections are Gordian Associates estimates, based on the methodology described in Appendix A.

case" (Exhibit 13); the price elasticity assumption of Exhibit 13 does not apply to this case. The results of the "constant real energy prices case" projections are contained in Exhibit 16. Exhibit 19 presents a graphic depiction of the projected relative amounts of commercial primary energy consumption for both the increasing and constant cases.

EXHIBIT 15. LDC COMMERCIAL ENERGY CONSUMPTION ASSUMPTIONS FOR ANNUAL GNP GROWTH RATE -- CONSTANT REAL ENERGY PRICES CASE

	<u>1976-1990</u>	<u>1990-2020</u>
Industrialized Countries	5.8%	5.8%
Balanced Growth Economies	5.8	5.8
Primary Exporters	3.8	3.8
Agricultural Countries	3.8	3.8
Current Oil Exporters	6.7	6.7

Consumption Projections by Geographic Region. Exhibits 17 and 18 present the consumption projections for the "increasing real energy prices case" and the "constant real energy prices case" respectively, in terms of the geographic regions used by the World Bank in its annual Atlas and other publications. The totals differ slightly ($\pm 2\%$) for future years due to the use of slightly different projection factors.

These projections show the dominance in commercial energy consumption of Latin America and Europe, the Middle East and North Africa, followed by East and South Asia. Three sub-Saharan African countries account for only 2% of the non-OPEC LDCs' total commercial energy consumption in 2020. This distribution reflects the geographic distribution used earlier, plus, in South Asia, the overwhelming consumption of India.

EXHIBIT 16. PROJECTED COMMERCIAL ENERGY CONSUMPTION FOR NON-OPEC LDCs --
 CONSTANT REAL ENERGY PRICES CASR
 (Thousands of Barrels of Oil Equivalent Per Day)

<u>Country Category</u>	<u>1976</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
<u>Industrialized Countries</u>				
Oil	2802	5311	8698	23346
Coal	857	1897	3764	13981
Primary Electricity	228	554	985	3104
Natural Gas	<u>245</u>	<u>509</u>	<u>871</u>	<u>2581</u>
Total	4132	8271	14228	43012
<u>Balanced Growth Economies</u>				
Oil	1363	3062	5334	16249
Coal	1557	3535	6446	20982
Primary Electricity	115	448	933	3720
Natural Gas	<u>141</u>	<u>365</u>	<u>677</u>	<u>2274</u>
Total	3176	7410	13390	43225
<u>Primary Exporters</u>				
Oil	169	259	374	780
Coal	24	48	71	156
Primary Electricity	19	34	57	146
Natural Gas	<u>1</u>	<u>2</u>	<u>3</u>	<u>7</u>
Total	213	343	505	1089
<u>Agricultural Countries</u>				
Oil	611	991	1421	2932
Coal	22	45	79	226
Primary Electricity	37	64	110	305
Natural Gas	<u>15</u>	<u>20</u>	<u>30</u>	<u>65</u>
Total	685	1120	1640	3528
<u>Current Oil Exporters</u>				
Oil	1128	2392	4183	13300
Coal	92	280	612	2727
Primary Electricity	45	170	329	1230
Natural Gas	<u>321</u>	<u>768</u>	<u>1427</u>	<u>4992</u>
Total	1586	3610	6551	22249
<u>All Countries</u>				
Oil	6070	12015	19920	56607
Coal	2552	5805	10972	38072
Primary Electricity	444	1270	2414	8505
Natural Gas	<u>723</u>	<u>1664</u>	<u>3008</u>	<u>9919</u>
Total	9789	20754	36314	113103

Source: 1976 consumption data from United Nations Statistical Paper
 Series J. No. 20. World Energy Supplies 1972-1976. New York:
 1978. Projections are Gordian Associates estimates.

EXHIBIT 17. PROJECTED COMMERCIAL ENERGY CONSUMPTION FOR NON-OPEC LDCs
BY GEOGRAPHIC DISTRIBUTION -- INCREASING REAL ENERGY PRICES CASE
(Thousands of Barrels of Oil Equivalent Per Day)

	1976	1980	1985	1990	2000	2010	2020
<u>Eastern Africa</u>							
Oil	138	157	231	272	302	323	421
Coal	24	33	43	66	73	92	141
Primary Electricity	23	24	42	72	84	115	174
Natural Gas	0	0	0	0	0	0	0
Total	185	214	316	410	459	530	736
<u>Western Africa</u>							
Oil	111	127	150	178	198	213	281
Coal	0	0	0	0	0	0	0
Primary Electricity	13	16	21	29	37	45	68
Natural Gas	1	1	2	2	3	4	6
Total	125	144	173	209	238	262	355
<u>Europe, Middle East & North Africa</u>							
Oil	1965	2390	3062	3924	4927	6005	8902
Coal	743	926	1233	1643	2332	3211	5569
Primary Electricity	100	137	187	256	352	470	765
Natural Gas	92	115	151	199	253	334	503
Total	2900	3568	4633	6021	7864	10020	15739
<u>East Asia & Pacific</u>							
Oil	778	902	1088	1312	1514	1702	2338
Coal	230	422	567	761	1097	1534	2602
Primary Electricity	19	25	34	48	67	93	156
Natural Gas	0	0	0	0	0	0	0
Total	1027	1349	1689	2121	2678	3329	5096
<u>South Asia</u>							
Oil	510	628	820	1071	1375	1714	2597
Coal	1305	1642	2329	2964	4279	5984	10165
Primary Electricity	67	85	113	152	201	257	398
Natural Gas	147	181	236	308	408	503	772
Total	2029	2536	3498	4495	6263	8458	13932
<u>Latin America & Caribbean</u>							
Oil	2568	3116	3974	5074	6386	7804	11607
Coal	249	314	425	576	855	1234	2172
Primary Electricity	220	286	388	527	722	958	1548
Natural Gas	484	607	800	1066	1444	1899	3038
Total	3521	4323	5587	7243	9407	11895	18365
<u>Total LDCs</u>							
Oil	6070	7320	9325	11831	14702	17761	26146
Coal	2551	3337	4597	6009	8636	12055	20649
Primary Electricity	442	573	785	1084	1463	1938	3109
Natural Gas	724	904	1189	1575	2108	2740	4319
Total	9787	12134	15896	20499	26909	34494	54223

EXHIBIT 18. PROJECTED COMMERCIAL ENERGY CONSUMPTION FOR NON-OPEC LDCs BY
GEOGRAPHIC DISTRIBUTION -- CONSTANT REAL ENERGY PRICES CASE
(Thousands of Barrels of Oil Equivalent Per Day)

	<u>1976</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
<u>Eastern Africa</u>							
Oil	138	157	231	272	355	461	601
Coal	24	33	43	66	86	132	202
Primary Electricity	23	24	42	72	99	164	248
Natural Gas	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	185	214	316	410	540	757	1051
<u>Western Africa</u>							
Oil	111	127	150	178	233	304	401
Coal	0	0	0	0	0	0	0
Primary Electricity	13	16	21	29	43	64	97
Natural Gas	<u>1</u>	<u>1</u>	<u>2</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>8</u>
Total	125	144	173	209	279	373	506
<u>Europe, Middle East & North Africa</u>							
Oil	1965	2390	3062	3924	5796	8578	12717
Coal	743	926	1233	1642	2743	4587	7956
Primary Electricity	100	137	187	256	414	672	1093
Natural Gas	<u>92</u>	<u>115</u>	<u>151</u>	<u>199</u>	<u>298</u>	<u>477</u>	<u>718</u>
Total	2900	3568	4633	6021	9251	14314	22484
<u>East Asia & Pacific</u>							
Oil	778	902	1088	1312	1781	2431	3340
Coal	230	422	567	761	1291	2191	3717
Primary Electricity	19	25	34	48	79	133	223
Natural Gas	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	1027	1349	1689	2121	3151	4755	7280
<u>South Asia</u>							
Oil	510	628	820	1071	1618	2449	3710
Coal	1305	1642	2329	2964	5034	8549	14522
Primary Electricity	67	85	113	152	236	367	569
Natural Gas	<u>147</u>	<u>181</u>	<u>236</u>	<u>308</u>	<u>480</u>	<u>719</u>	<u>1103</u>
Total	2029	2536	3498	4495	7368	12084	19904
<u>South America</u>							
Oil	2568	3116	3974	5074	7513	11149	16582
Coal	249	314	425	576	1006	1763	3103
Primary Electricity	220	286	388	527	849	1368	2211
Natural Gas	<u>484</u>	<u>607</u>	<u>800</u>	<u>1066</u>	<u>1699</u>	<u>2713</u>	<u>4340</u>
Total	3521	4323	5587	7243	11067	16993	26236
<u>Total</u>							
Oil	6070	7320	9325	11831	17296	25372	37351
Coal	2551	3337	4597	6009	10160	17222	29500
Primary Electricity	442	573	785	1084	1720	2768	4441
Natural Gas	<u>724</u>	<u>904</u>	<u>1189</u>	<u>1575</u>	<u>2480</u>	<u>3914</u>	<u>6169</u>
Total	9787	12134	15896	20499	31656	49276	77461

EXHIBIT 19. PROJECTED LDC COMMERCIAL PRIMARY ENERGY CONSUMPTION UNDER
DIFFERING ASSUMPTIONS

Increasing Real Energy Prices Case

Constant Real Energy Prices Case

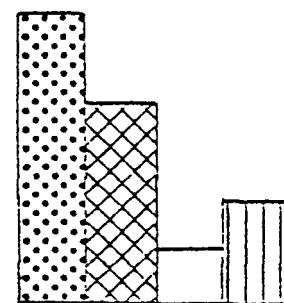
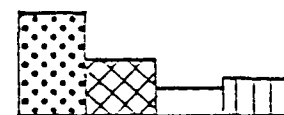
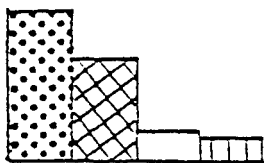
1990



2000



2020



Oil

Coal

Primary Electricity

Natural Gas

2.1.2. LDC Demand for Noncommercial Energy

Although a few studies have attempted to draw together the disjointed and thoroughly inadequate information available on noncommercial fuel use, they provide no real basis for an estimation of its current use. For the purposes of this report, we have assumed that the per capita use of noncommercial energy is 400 kilograms coal equivalent per year. This corresponds to about one ton of wood per year, or the equivalent of a three inch lump of coal per person per day. Other estimates in the literature range from slightly less to several times the value used here for per capita consumption, which is almost assuredly conservative. Indeed, it is difficult to reconcile the per capita consumption level with the services, such as cooking, known to be provided by noncommercial fuels. A detailed discussion of noncommercial energy, its role in subsistence and development, and the shortcomings of data and projections may be found in Section 2.2.2.

The assumed population growth rates used to project noncommercial energy demand into the future are presented in Exhibit 20 for each country group. Projections of noncommercial energy demand are shown by country group in Exhibit 21.

EXHIBIT 20. POPULATION GROWTH
(Millions)

	<u>1975</u>	<u>%</u>	<u>1990</u>	<u>%</u>	<u>2000</u>	<u>%</u>	<u>2020</u>
Industrialized Countries	262	2.5	380	2.4	480	2.3	760
Balanced Growth Economies	784	2.5	1140	2.4	1445	2.3	2280
Primary Exporters	61	2.5	88	2.4	110	2.3	180
Agricultural Countries	398	2.7	600	2.6	770	2.5	1260
Current Oil Exporters	134	2.5	194	2.5	250	2.4	400
Total	1639	2.6	2402	2.6	3055	2.5	4880

Source: Gordian Associates Inc.

EXHIBIT 21. PROJECTED NONCOMMERCIAL ENERGY CONSUMPTION
(Thousands of Barrels of Oil Equivalent Per Day)

	<u>1975</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
Industrialized Countries	1350	1960	2460	3960
Balanced Growth Economies	4040	5880	7415	11760
Primary Exporters	320	445	570	920
Agricultural Countries	2045	3100	3975	6515
Current Oil Exporters	690	1000	1290	2080
Total	8445	12385	15840	25235

Source: Policy Analysis Division, National Center for Analysis of Energy Systems, Brookhaven National Laboratory, Overseas Development Council, and Gordian Associates.

2.2 ENERGY SUPPLY

2.2.1 LDC Commercial Energy Supply to 1990 and 2020

Non-OPEC LDCs produced 7.7 million barrels of (MMBD) oil equivalent per day of primary energy in 1975 (3.8 MMBD oil, 2.4 MMBD coal, 1.0 MMBD natural gas, and 0.5 MMBD primary electricity). Production in 1976 was slightly lower: 7.4 MMBD (3.6 MMBD oil, 2.4 MMBD coal, 0.9 MMBD natural gas, and 0.5 MMBD primary electricity). A geographic breakdown of 1976 production is presented in Exhibit 22.

In 1990, depending on the rate of additions to world oil reserves,* the non-OPEC LDC production potential is 22.5 to 28.8 MMBD of primary energy (11.3-15.2 MMBD oil, 6.0-6.4 MMBD coal, 3.6-5.9 MMBD natural gas, and 1.7 MMBD of primary electricity) primarily hydroelectric and nuclear electricity generation. By 2020 our projection is 106-138 MMBD of primary energy (34-66 MMBD of oil, 36-53 MMBD of coal, 9-26 MMBD of natural gas, and 11 MMBD of primary electricity).

The newly-revised oil projections are based on a detailed analysis of updated LDC production patterns, proved reserves, reserve addition rates, recovery rates, wildcat success rates, regional drilling densities, oil market shifts in crude quality preferences, and government policies.

* See footnote, Exhibit 6, page 10.

EXHIBIT 22. COMMERCIAL ENERGY PRODUCTION OF NON-OPEC LDCs, 1976
(Thousands of Barrels of Oil Equivalent Per Day)

	<u>Coal</u>	<u>Oil</u>	<u>Gas</u>	<u>Hydro</u>	<u>Total</u>
Eastern Africa	16.678	24.150	0	22.850	63.678
Western Africa	0	125.397	0.657	13.027	139.081
Europe, Middle East & North Africa	618.268	1160.330	143.362	113.789	2035.749
East Asia & Pacific	220.749	0.158	0	18.661	239.568
South Asia	1354.093	391.688	260.907	74.038	2080.726
Latin America & Caribbean	<u>189.140</u>	<u>1944.061</u>	<u>475.720</u>	<u>222.141</u>	<u>2831.062</u>
Total	2.4MMBD	3.6MMBD	0.9MMBD	0.5MMBD	7.4MMBD

Source: UN Statistical Series J.

EXHIBIT 23. LDC COMMERCIAL ENERGY SUPPLY TO 1990 AND 2020
(MMBD Oil Equivalent)

	<u>1976</u>	<u>1990</u>	<u>2020</u>
<u>High Reserves Addition Case</u>			
Oil	3.6	15.2	65.6
Coal	2.4	6.0	36.5
Primary Electricity	.5	1.7	10.7
Natural Gas	<u>0.9</u>	<u>5.9</u>	<u>25.5</u>
Total	7.4	28.8	138.2
<u>Medium Reserves Addition Case</u>			
Oil	3.6	13.3	48.9
Coal	2.4	6.0	38.7
Primary Electricity	0.5	1.7	10.7
Natural Gas	<u>0.9</u>	<u>4.6</u>	<u>17.1</u>
Total	7.4	25.7	115.4
<u>Low Reserves Addition Case</u>			
Oil	3.6	11.3	33.6
Coal	2.4	6.4	53.0
Primary Electricity	0.5	1.7	10.7
Natural Gas	<u>0.9</u>	<u>3.0</u>	<u>8.8</u>
Total	7.4	22.5	106.1

Oil Production. Exhibit 24 shows the distribution of 1977 world oil production. Although non-OPEC LDCs produced only 7% of 1977 world oil, their production gain over 1976 was 19%, or 695,000 barrels per day. Production gains in all Communist areas totalled 697,000 barrels per day (+ 5.6%), in developed countries 583,000 BPD (+ 5%), and in OPEC nations 348,000 BPD (+ 1%).

Production gains recorded in the oil-exporting LDCs in 1977 included Mexico's 190,000 daily barrels (+ 24%), Egypt's 122,000 (+ 37%), Angola's 95,000 (+ 96%), Malaysia's 40,000 (+ 26%), Trinidad/Tobago's 18,000 (+ 8%), Tunisia's 14,000 (+ 19%), Congo's 5,000 (+ 15%), Syria's 9,000 (+ 5%), and Brunei's 7,000 (+ 3%). Oil-exporter production declines in 1977 were: Oman, 16,000 barrels (- 4%); Bolivia, 5,000 barrels (- 5%); and Bahrain, 4,000 (- 4%). Exhibit 25 displays oil production changes for oil exporting countries from 1976 to 1977.

EXHIBIT 24. 1977 WORLD OIL PRODUCTION

	1977 Production (MMBD)	World Percent
Current Oil Exporters	3.0	5
Industrialized Countries	0.7	1
Balanced Growth Economies	0.5	1
Primary Exporters,	0.02	-
Agricultural Exporters	<u>0.02</u>	<u>-</u>
Total Non-OPEC LDCs	4.3	7
Developed Countries	11.2	19
OPEC	30.7	52
Communist Areas	<u>13.0</u>	<u>22</u>
Total World	59.2	100

Source: Oil and Gas Journal.

EXHIBIT 25. OIL-EXPORTING LDC OIL PRODUCTION CHANGES IN 1977 FROM 1976

<u>Increases</u>	<u>Change %</u>	<u>Total 1977 Production (Thousand Barrels/day)</u>	<u>1977 Change From 1976 (Thousand Barrels/day)</u>
Angola-Cabinda	+ 95.5	195	+ 95
Egypt	+ 37.2	450	+122
Malaysia	+ 26.0	190	+ 40
Mexico	+ 23.6	990	+190
Tunisia	+ 19.2	87	+ 14
Congo	+ 14.6	35	+ 5
Trinidad/Tobago	+ 8.5	230	+ 18
Syria	+ 4.7	200	+ 9
Brunei	+ 3.5	207	+ 7
<u>Decreases</u>			
Bolivia	- 12.5	35	- 5
Bahrain	- 6.9	54	- 4
Oman	- 4.4	350	- 16
Totals	+ 27.0	3023	+637

The factors affecting the future world production of oil will include:

- Proved Crude Oil Reserves: Some 7% of the world's present proved crude oil reserves, or 44 billion barrels, is in non-OPEC LDCs. Ten percent is in the developed countries, 15% in Communist areas, and 68% in OPEC. Of the reserves in non-OPEC LDCs, 34 billion barrels are in oil-exporting countries, 5.5 billion in countries with balanced economies, 4.4 billion in industrialized countries, and very limited reserves are found in other LDCs. Current production within LDC groups roughly approximates this proportion. By 1990 we estimate the exporters' share of LDC production (and reserves) will have declined slightly as new fields are brought into production in oil-importing LDCs. Despite very large increases in Mexico, the exporters' share will have declined to about half of LDC reserves and production by 2020. (See Exhibits 26 and 27.)

- Additions to Reserves: The world's proved reserves of crude oil increased by 47 billion barrels (+ 7%) during 1977. Reserves in Communist areas, as reported by Oil and Gas Journal, decreased by 3 billion barrels. In the rest of the world, OPEC registered 81% of the increase (nearly all in Saudi Arabia), the developed countries 3%, and non-OPEC LDCs 16%. Mexico added a conservative estimate of 7 billion barrels to its proved reserves. But eight other LDCs contributed 0.1 billion or more to the remaining LDC reserves increase: Egypt 0.5 billion, Chile 0.26 billion, Pakistan 0.2 billion, Argentina 0.2 billion, Colombia 0.1 billion, Trinidad/Tobago 0.1 billion, Bolivia 0.1 billion, and the Philippines 0.1 billion. Zaire, on the other extreme, had its reserve estimate reduced by 0.35 billion, Spain by 0.17 billion, and Oman by 0.16 billion. (See Exhibit 28).
- Ratio of Reserve Additions to Production: Non-OPEC LDCs ended 1977 with their proved reserves increased by 1.8 times 1977 production. Developed countries added only 40% more than they produced; OPEC added 3.6 times what it produced; and LDC oil exporters added 2.5 times what they produced. Industrialized and balanced economy LDCs added to their reserves only about 60% of what they produced in 1977. Reserves declined in the primary exporters and agricultural countries. We expect these lower income groups' share of LDC oil production to erode for the next several years. But by 2020, they are likely to account for 20% of LDC oil production. (See Exhibit 29.)

EXHIBIT 26. "WORLD SHARE" ESTIMATED PROVED CRUDE OIL RESERVES AS OF 1/1/78

	<u>Billion Barrels</u>	<u>Percent</u>
Non-OPEC LDCs	43.8	7
Current Oil Exporters	33.7	(5)
Balanced Growth Economies	5.5	(1)
Industrialized Countries	4.4	(1)
Primary Exporters	.2	-
Agricultural Exporters	.02	-
Other Agricultural	.02	-
Developed Countries	63.9	10
Communist Areas	98.0	15
OPEC	<u>439.9</u>	<u>68</u>
Total	645.6	100

Source: Oil & Gas Journal and World Oil.

EXHIBIT 27. ESTIMATED PROVED CRUDE OIL RESERVES OF SELECTED LDCs
(In Billions of Barrels)

<u>Oil Exporters</u>	<u>1/1/76*</u>	<u>1/1/77*</u>	<u>1/1/78*</u>	<u>% Change in 1976</u>	<u>% Change in 1977</u>
Mexico	3.4	8.0	14.0	+ 135	+ 75
Oman	3.3	3.2	5.7	- 3	+ 78
Tunisia	2.3	2.3	2.7	-	+ 17
Egypt	1.4	1.6	2.5	+ 14	+ 56
Malaysia	1.5	1.5	2.5	-	+ 67
Brunei	1.9	1.9	1.55	-	- 18
Syria	2.7	2.6	2.2	- 4	- 15
Angola	1.4	1.3	1.2	- 7	- 8
Trinidad/Tobago	0.65	0.65	0.65	-	-
Congo	.49	.78	.36	- 2	- 25
Bolivia	.14	.15	.35	+ 7	+ 133
Total	19.18	23.98	33.71	+ 26	+ 44
<u>Oil Importers</u>					
India	1.07	3.0	3.0	+ 180	-
Argentina	2.5	2.5	2.5	-	-
Brazil	.78	.81	.88	+ 4	+ 9
Peru	.75	.73	.73	- 3	-
Turkey	.1	.1	.37	-	+ 270
Yugoslavia	.37	.34	.33	- 8	- 3
Pakistan	.026	.086	.280	+ 231	+ 226
Spain	.26	.25	.26	-	+ 4
Zaire	.14	.14	.15	-	+ 7
Philippines	NA	NA	.1	NA	NA
Afghanistan	NA	NA	.084	NA	NA
Burma	.067	.063	.055	- 6	- 13
Greece	.137	.137	.025	-	- 82
Taiwan	.019	.018	.012	- 5	- 33
Total	6.22	8.17	10.6	+ 31	+ 30

* World Oil, August 15, 1977; does not include condensate.

** Oil and Gas Journal, December 26, 1977; includes condensate.

EXHIBIT 28. WORLD SHARES OF ADDITIONS TO ESTIMATED CRUDE OIL RESERVES*
BETWEEN 1/1/77 and 1/1/78

	<u>Millions of Barrels</u>	<u>Billions of Barrels</u>	<u>Percent</u>
Non-OPEC LDCs**		7.9	16
<u>Current Oil Exporters</u>		+ 7.5	
Mexico	+ 7000		
Egypt	+ 500		
Trinidad/Tobago	+ 130		
Bolivia	+ 110		
Congo	+ 75		
Malaysia	+ 70		
Tunisia	- 30		
Angola	- 50		
Syria	- 50		
Brunei	- 75		
Oman	- 160		
Total	7520		
<u>Industrialized Countries</u>		+ .34	
Chile	+ 258		
Argentina	+ 203		
Brazil	+ 80		
Taiwan	- 3		
Yugoslavia	- 25		
Spain	- 175		
Total	338		
<u>Balanced Growth Economies</u>		+ .39	
Pakistan	+ 205		
Colombia	+ 135		
Philippines	+ 100		
Greece	- 15		
Peru	- 17		
Turkey	- 20		
Total	388		
<u>Primary Exporters</u>		- .35	
Morocco	- .05		
Zaire	- 350		
Total	- 350.05		

EXHIBIT 28. WORLD SHARES OF ADDITIONS TO ESTIMATED CRUDE OIL RESERVES
BETWEEN 1/1/77 and 1/1/78 (cont'd.)

	<u>Millions of Barrels</u>	<u>Billions of Barrels</u>	<u>Percent</u>
<u>Agricultural Exporters</u>		- .005	
Thailand	+ .13		
Guatemala	- 5		
Total	- 4.87		
<u>Other Agricultural</u>		+ .051	
Cameroon	+ 60		
Afghanistan	- 1		
Burma	- 8		
Total	+ 51		
DEVELOPED COUNTRIES		+ 1.6	3
OPEC		<u>40.9</u>	<u>81</u>
Subtotal (LDCs, OPEC, DCs)		+ 50.4	100
Communist Areas		- <u>3.1</u>	
Total World		+ 47.3 (billions)	

* Includes condensate.

** Countries not shown if oil reserves were unchanged.

Source: Oil and Gas Journal, December 27, 1976, December 26th.

EXHIBIT 29. RATIO OF 1977 CRUDE OIL RESERVE ADDITIONS TO 1977 PRODUCTION

	Reserve Additions (Billion bbls)	Production (Billion bbls)	Ratio RA/P
Non-OPEC LCDs	7.9	4.3	1.8
Current Oil Exporters	7.5	3.0	2.5
Balanced Growth Economies	.39	.7	.6
Industrialized Countries	.34	.5	.6
Other Agricultural	.05	.02	0
Agricultural Exporters	- .005	0	-
Primary Exporters	- .35	.02	0
Developed Countries	1.6	4.09	.4
OPEC	40.9	11.2	3.6
Communist Areas	- 3.1	4.7	--
World Total	47.3	21.6	2.2

The potential for successful increased oil drilling will be determined by the following:

- Wildcat Success Rates: Both the extent of drilling and degree of success vary widely among the various LDC country groups. Most of the 1975-76 drilling activity took place in the oil exporters, industrialized, and balanced growth groups, and resulted in generally higher success rates.

The total number of wells drilled in LDCs dropped from 571 in 1975 to 520 in 1976, but the number of successful wells increased from 130 to 159. The overall success rate climbed from 23% to 31% in 1976. Only oil exporters exceeded the average success rate for the non-Communist world. Other LDC groups are likely to improve their rates gradually through 2020. (See Exhibit 30.)

- Drilling Densities: Whereas OPEC countries have 4 million square miles of prospective petroleum areas (sedimentary basins onshore plus offshore to 200 meters depth and the U.S. 3 million, non-OPEC LDCs have some 13 million square miles: Latin American LDCs 4.5 million, African LDCs 3.6 million, Mideast LDCs 2.8 million, and Asian LDCs 2.0 million.

But drilling density (total number of wells drilled in this century per square mile of prospective petroleum area) in non-OPEC LDCs averages 1% of U.S. drilling density: African and Mideast LDCs 0.1%, Asian LDCs 0.7%, and Latin American LDCs 2%. (Exhibit 31.) Only three of the oil-exporting LDCs have sufficient drilling densities: Trinidad/Tobago (90% of U.S.), Bahrain (85%), and Brunei (32%). Mexico, where considerable reserve additions should be expected, has had only 0.04 wells drilled per prospective square mile (5% of U.S. density). (Exhibit 32.)

OPEC's current domination of the world's oil market derives from the comparative advantage it enjoyed in the giant size of fields it discovered and miniscule per-gallon crude production costs. But as the technology of oil exploration and development improves, and as the major oil companies who were responsible for the development of OPEC oil production are expropriated (making their crude acquisition costs from OPEC countries closer to \$13 than the earlier 13¢ per barrel), greater opportunity exists for LDCs to attract the necessary technology and capital investment for more successful development of their oil and gas potential. (Exhibit 32.)

- Market Quality Preferences: Future world oil demand is likely to put a greater premium on the discovery and production of lighter (higher gravity), sweeter (lower sulfur) crude streams. OPEC countries are producing as much of their lighter reserves as possible and are likely to deplete these reserves faster than their reserves of heavier oil. In 1976 OPEC produced 5.6 million barrels of crude 37° or lighter -- 19% of production. But most OPEC countries are weak in light oil reserves. Only Algeria, the U.A.E., and Libya produced mostly light oil in 1976 (see Exhibit 33).
- Recent Developments in Government Policies: Despite increasing nationalization and expropriation moves in most OPEC countries, some LDCs are offering foreign oil companies with advanced technology some ownership participation as an incentive for their provision of investment and technology into the development of LDC oil potential. Angola, with the counsel of Algerian oil experts, continues to offer participation to international oil companies. Argentina and Brazil have ended government oil monopolies and invited participation by foreign companies. Those LDCs offering equity participation to foreign oil companies and who have enjoyed oil discoveries in recent years as a result include: Chad, Ivory Coast, Niger, Zaire, Peru, and Malaysia.

EXHIBIT 30. LDCs' WILDCAT SUCCESS RATES IN 1975 AND 1976*

	<u>Total Wildcats</u>		<u>Successful</u>		<u>% Successful</u>
	<u>1975</u>	<u>1976</u>	<u>1975</u>	<u>1976</u>	<u>1975-1976</u>
Total Non-OPEC LDCs	570	520	130	159	25
<u>Current Oil Exporters</u>	87	79	13	24	22
Mexico	87	79	13	24	22
Egypt	20	34	18	2	37
Trinidad/Tobago	14	23	9	6	40
Malaysia	11	10	0	0	0
Angola	10	5	7	5	80
Tunisia	8	10	8	4	37
Bolivia	7	16	0	7	30
Congo	4	-	0	-	0
Brunei	-	11	-	7	64
Sub-Total	161	116	55	55	40
<u>Industrialized Counties</u>					
Brazil	87	105	17	17	18
Argentina	78	83	22	25	29
Chile	23	22	7	5	27
Taiwan	18	10	2	-	7
South Korea	2	-	0	-	0
Uruguay	-	2	-	0	0
Sub-Total	208	222	48	47	22
<u>Balanced Growth Economies</u>					
Turkey	56	43	4	8	12
Peru	43	36	11	28	49
Colombia	14	21	3	8	31
Philippines	13	8	0	0	0
Pakistan	5	1	0	1	17
Greece	-	1	-	0	-
Sub-Total	131	110	18	45	25
<u>Primary Exporters</u>					
Morocco	5	8	5	1	46
Zaire	4	2	0	1	17
Guyana	3	-	0	-	0
Mauritania	2	-	0	-	0
Sub-Total	14	10	5	2	29

EXHIBIT 30. LDCs' WILDCAT SUCCESS RATES IN 1975 AND 1976*(cont'd.)

	<u>Total Wildcats</u>		<u>Successful</u>		<u>% Successful</u>
	<u>1975</u>	<u>1976</u>	<u>1975</u>	<u>1976</u>	<u>1975-1976</u>
<u>Agricultural Exporters</u>					
Thailand	10	17	0	0	0
Guatemala	3	5	1	1	25
Ivory Coast	3	1	0	0	0
Costa Rica	1	-	0	-	0
Honduras	1	-	0	-	0
Senegal	1	2	0	0	0
Sri Lanka	-	3	-	-	-
Sub-Total	19	28	1	1	4
<u>Other Agricultural</u>					
Burma	10	9	0	0	0
Cameroon	7	7	1	7	57
Ghana	5	-	0	0	0
Niger	5	-	0	-	0
Chad	4	4	2	1	37
Nicaragua	2	-	0	-	0
Lesotho	1	-	0	-	0
Paraguay	1	1	0	0	0
Somalia	1	1	0	0	0
Surinam	1	-	0	-	0
Bangladesh	-	5	-	0	0
Sudan	-	2	-	0	0
Tanzania	-	3	-	1	33
Sub-Total	37	34	3	3	17
Developed Countries	11,209	12,022	2890	1379	29
OPEC	<u>38</u>	<u>319</u>	<u>137</u>	<u>73</u>	<u>31</u>
Total World Outside Communist Areas	12,137	12,861	3,157	3,551	85

Countries are not shown if no wildcat wells were drilled in 1975-76.

Source: Oil & Gas Journal.

EXHIBIT 31. WORLD OIL DRILLING DENSITIES THROUGH 1/1/78

	<u>Petroleum Prospective Area (Millions Square Miles)</u>	<u>Total Wells Drilled to 1/1/78 (Thousands bbls)</u>	<u>Wells per Prospective Square Miles</u>	<u>% of U.S. Density</u>
<u>Non-OPEC LDCs</u>				
Latin America LDCs	4.5	75.0	.017	2
African LDCs	3.6	3.9	.001	0.1
Mideast LDCs	2.8	2.2	.001	0.1
Asia LDCs	<u>2.0</u>	<u>11.5</u>	<u>.006</u>	<u>0.7</u>
Total LDCs	12.9	92.6	.007	0.9
<u>OPEC</u>				
<u>Developed Countries</u>				
U.S.A.	3.1	2425	.78	100
Australia/N.Z.	2.4	2.5	.001	0.1
Canada	1.9	150	.08	10
Western Europe	1.4	50	.04	5
Japan	<u>.2</u>	<u>5.3</u>	<u>.03</u>	<u>0.1</u>
Total Developed	9.0	2632.8	.29	37
<u>Communist Areas</u>				
U.S.S.R.	3.5	530	.15	19
China	<u>1.1</u>	<u>8.5</u>	<u>.008</u>	<u>1</u>
Total	4.6	538.5	.117	15
World Total	30.5	3326.6	.109	

Source: Data compiled from Bernardo Grossling, Window on Oil: A Survey of World Petroleum Resources. London: The Financial Times Ltd., 1976.

EXHIBIT 32. DRILLING DENSITY IN OIL-EXPORTING LDCs

	Petroleum Prospective Area* (Thousand Square Miles)	Wells Drilled To End of 1977 (Thousand bbls)	Well per Prospective Square Mile	% of U.S. Density
<u>Non-OPEC Oil Exporting LDCs</u>				
Mexico	435	18.6	.04	5
Oman	60	.5	.008	1
Tunisia	83	.3	.004	0.4
Egypt	355	1.4	.004	0.5
Malaysia	91	.4	.004	0.6
Syria	40	.3	.008	1
Brunei	6	1.5	.25	32
Angola	45	.6	.013	2
Trinidad/Tobago	13	9.2	.71	90
Congo	31	.1	.003	0.4
Bolivia	<u>254</u>	<u>.9</u>	<u>.004</u>	<u>0.5</u>
Total LDCs	1413	33.8		
<u>OPEC</u>				
Venezuela	177	30.4	.17	22
Ecuador	<u>78</u>	<u>3.1</u>	<u>.04</u>	<u>5</u>
Total LA OPEC	255	33.5		
Algeria	640	2.9	.005	0.6
Libya	575	3.6	.006	0.8
Nigeria	175	2.8	.016	2
Gabon	<u>41</u>	<u>.9</u>	<u>.02</u>	<u>3</u>
Total Africa OPEC	1431	10.2		
Saudi Arabia	560	2.5	.004	0.6
Kuwait	6	1.3	.22	28
Iraq	100	.5	.005	0.6
Iran	380	1.3	.003	0.4
U.A.E.	20	.8	.04	5
Qatar	<u>3</u>	<u>.2</u>	<u>.07</u>	<u>9</u>
Total Mideast OPEC	1069	6.6		
Indonesia	1245	12.4	.01	1
Total OPEC	4000	62.7	.02	2

Sources: Sedimentary areas estimated by Bernardo Grossling, drilling data from Grossling, World Oil and Oil and Gas Journal.

EXHIBIT 33. 1976 OPEC PRODUCTION OF LIGHT CRUDE
(37° API or Above)

	Million Barrels Per Day	Light as % Output
U.A.E.	1.5	80
Libya	1.1	57
Algeria	1.1	98
Saudi Arabia	0.8	9
Nigeria	0.6	31
Indonesia	0.4	27
Venezuela	0.1	3
Gabon	.01	5
Iran	0	0
Kuwait	0	0
Iraq	0	0
Ecuador	0	0
Total	5.6	19

Natural Gas Production. Non-OPEC LDCs produced 6.6 billion cubic feet per day of natural gas in 1977, or 6% of world gas production. OPEC produced 9% and developed countries 56% (see Exhibit 34). This reflects the fact that huge quantities of natural gas produced in association with crude oil are still flared or reinjected into oil fields in order to maintain pressure. Heavy long-distance transport costs have kept gas relatively uneconomic to export. But increased gas prices in consuming countries have renewed investment interest in some long-distance gas export projects. Most gas production in LDCs far from developed country consumption centers, however, is likely to be consumed locally, including gas used in energy intensive export-oriented industry.

Gas reserves and additions to reserves are as follows:

- Gas Reserves: LDC gas reserves increased 31% in 1977 (after a 26% increase in 1976) to 145 trillion cubic feet (tcf). Three LDCs had more than 15 tcf: Mexico 30, Malaysia 17, and Pakistan 15.5. Nineteen LDCs had more than 1 tcf. (Exhibit 35.) The LDC share of 1977 additions to world reserves (net of 1977 production) was 12%. OPEC added 87% and Communist areas 1% of the increase. Developed countries' reserves decreased by 9.2 tcf. (Exhibit 36.)

EXHIBIT 34. GAS PRODUCTION, JANUARY-OCTOBER 1977

	<u>Billion Cubic Feet</u>	<u>Percent of World</u>
Non-OPEC LDCs	2305	5.0
Industrialized Countries	523	1.2
Balanced Growth Economies	201	0.5
Primary Exporters	24	0.05
Agricultural Exporters	-	-
Other Agricultural	108	0.25
Current Oil Exporters	1448	3.3
Developed Countries	24106	56
OPEC	3897	9
Communist Areas	<u>12952</u>	<u>30</u>
World Total	43350	100

- Additions to Reserves: Non-OPEC LDCs added to gas reserves 9.3 times what they produced in 1977. LDC oil exporters added to gas reserves 16.4 times what they produced in 1977. Industrial countries added reserves equal to one-third of their production in 1977. Agricultural exporters raised their estimate of reserves but produced no gas in that year. The countries in the balanced economies category depleted their reserves by 3.8 trillion cubic feet, and the reserves of gas held constant in the primary exporters and other agricultural groups.

Gas production will be constrained by conservation and oil-preference policies over the next decade. Gas production potential is high in such countries as Pakistan, India, and Afghanistan. But long gathering and transport system leadtimes will dampen the annual increase through 1990.

By 2020 we expect the LDC oil exporters to produce about 55% of LDC natural gas, while the more affluent LDCs (over \$500 per capita income per year) will produce about 28% with the balance, 17%, being produced in LDCs with per capita income below \$500 per year.

Coal Production. Coal production in non-OPEC LDCs in 1976 was 2.4 million barrels per day oil equivalent, or 6% of total world production. LDC coal production increased 7.2% per year from 1973-1976 (5.4% from 1971-1976). Of the LDC country groups, only the oil exporters slowed their annual rate of coal production increase after 1973 (8.9% in 1973-1976 versus 9.4% in 1971-1976). Balanced growth economies increased their coal production 8.8% per year in 1973-

EXHIBIT 35. ESTIMATED PROVED GAS RESERVES OF SELECTED LDCs
(Trillion Cubic Feet)

	<u>1-1-76</u>	<u>1-1-77</u>	<u>1-1-78</u>	<u>% chg in 76</u>	<u>% chg in 77</u>
E Mexico	11.9	20.5	30.0	+ 72	+ 46
E Malaysia	12.0	12.0	17.0	-	+ 42
E Pakistan	11.1	14.9	15.5	+ 34	+ 4
E Trinidad/Tobago	4.0	8.0	8.5	+100	+ 6
E Brunei	6.6	6.4	8.25	- 3	+ 29
Argentina	7.1	7.1	8.12	-	+ 14
Bangladesh	na	na	8.0	na	na
Columbia	4.5	6.4	6.4	+ 42	-
Tunisia	6.6	6.6	6.4	-	- 3
E Bolivia	3.8	3.9	5.0	+ 3	+ 28
Thailand	na	4.4	4.5	na	+ 2
Greece	.05	.05	4.0	-	-
India	3.1	3.5	3.5	+ 13	-
Egypt	2.2	2.2	3.2	-	+ 45
Syria	2.7	2.6	3.1	- 4	+ 19
E Afghanistan	na	na	2.6	na	na
Chile	2.3	2.4	2.0	+ 4	+ 17
Oman	2.4	2.3	2.0	- 4	- 13
Angola	1.7	1.5	1.5	- 12	-
Yugoslavia	1.5	1.4	1.4	- 7	-
Peru	1.3	1.3	1.3	-	-
Brazil	.92	.95	1.2	+ 3	+ 26
Taiwan	1.0	1.0	.7	-	- 30
Turkey	.02	.02	.54	-	-
Spain	.4	.4	.2	-	- 50
Burma	.2	.2	.15	-	- 25
Sudan	na	na	.1	na	na
Tanzania	na	na	.05	na	na
Zaire	.07	.07	.05	-	- 29
Morocco	.01	.01	.04	-	+300
Congo	1.0	1.0	.01	-	-
TOTAL	88.47	111.1	145.31	+ 26	+ 31

E = present gas exporter or export plans announced

Source: Oil and Gas Journal.

EXHIBIT 36. WORLD SHARES OF ADDITIONS TO ESTIMATED GAS RESERVES BETWEEN
1/1/77 and 1/1/78

	<u>1977 Gas Additions</u> <u>(Trillion Cubic Feet)</u>	<u>Percent</u>
Non-OPEC LDC	26.9	12
Industrialized Countries ^a	+ 0.2	
Balanced Growth Economies ^b	- 3.8	
Primary Exporters ^c	0	
Agricultural Exporters ^d	+ 3.5	
Other Agricultural ^e	0	
Current Oil Exporters ^f	+27.9	
Developed Countries	- 9.2	-
OPEC	+196.5	87
Communist Areas	+ 2.0	1
Total World Total A	+216.0	<u>100</u>

Source: Oil and Gas Journal and World Oil.

Note: Additions net after subtraction of 1977 production.

a. Argentina +1.32, Brazil +0.3, Spain -0.3, Taiwan -0.1, Yugoslavia -1.0.

b. Columbia +1.36, Greece -4.0, Pakistan -0.28, Peru -0.9.

c. Morocco +0.024.

d. Thailand +3.5.

e. Afghanistan -0.15, Sudan +0.1, Tanzania +0.05.

f. Mexico +18.0, Trinidad/Tobago +5.075, Malaysia +2.0, Syria +1.9,
Egypt +.4, Congo Rep. +.0003, Tunisia -2, Brunei -.15.

EXHIBIT 37. RATIO OF 1977 GAS RESERVES ADDITIONS TO 1977 PRODUCTION

	<u>Reserves Additions (Trillion Cubic Feet)</u>	<u>Production* (Trillion Cubic Feet)</u>	<u>Ratio RA/P</u>
Non-OPEC LDCs	+ 26.9	2.9	9.3
Industrialized Countries	+ 0.2		
Balanced Growth Economies	- 3.8		
Primary Exporters	0		
Agricultural Exporters	+ 3.5		
Other Agricultural	0		
Current Oil Exporters	+27.9		
Developed Countries	- 9.2	28.9	--
OPEC	+196.5	4.7	41.8
Communist Areas	+ 2.0	15.5	.13
Total World	+216.0	52.0	4.1

1976 (6.7% in 1971-1976), and industrialized countries increased their production 4.3% per year between 1973 and 1976 versus 2.6% for the period 1971-1976. None of the other LDC groups produced significant amounts of coal during this time. World coal production for 1976 is displayed in Exhibit 38.

During the long period of relatively low world oil prices, non-metallurgical coal's share of the energy market decreased. Exploration declined precipitously, and production declined relative to other fuels. Since 1973, however, there has been a renewed interest in coal. Several of the non-OPEC LDCs have launched programs to increase production, improve mine productivity, and discover additional reserves. There is also substantial research underway to improve boiler systems' capability to use low-grade lignite, brown coal, and even peat.

If LDC coal reserves to production ratio* is maintained, then they will have adequate supplies for between 150 and 200 years at their present consumption levels. Most

* Reserves is that fraction of resources that has been measured and assessed and that is recoverable under present local economic conditions using existing available technology. (Source: World Energy Conference.)

EXHIBIT 38. 1976 WORLD COAL PRODUCTION

	<u>% World Production 1976</u>	<u>1976 Production MMBDOE</u>	<u>1971-1976 Annual % Increase</u>	<u>1973-1976 Annual % Increase</u>
Non-OPEC LDCs	6.4	2.5	5.4	7.2
Industrialized Countries	2.0	.76	2.6	4.3
Balanced Growth Economies	4.0	1.74	6.7	8.8
Primary Exporters	-	.02	-	-
Agricultural Exporters	-	.004	-	-
Other Agricultural	-	.01	-	-
Current Oil Exporters	0.002	0.0007	-	-
Developed Countries	41	15.2	1.3	2.3
OPEC	0.0006	0.0002	63.0	2.5
Communist Areas	<u>53</u>	<u>19.6</u>	<u>3.2</u>	<u>3.2</u>
Total	100	39.5	2.5	3.0

Source: World Energy Supplies, Statistical Papers Series J, No. 20.
New York: United Nations, 1977.

experts believe that in view of the currently high level of coal reserves and the likelihood of substantially increasing them as exploration is intensified, coal reserve levels generally will not constitute the limitation on LDC coal utilization. Rather, the primary constraints are likely to be coal mine development and operating costs, manpower/training requirements, costs and lead-times to develop or upgrade necessary coal transportation systems (rail and/or barge), and the rate of investment in coal utilization facilities. Because two countries, India and Korea, together account for most non-OPEC coal production, they are addressed separately below.

In 1975 approximately 35.7% by weight of the solid fuel produced in non-OPEC LDCs was lignite. The heat value of lignite ranges from 33% (Greece, India, Thailand, Turkey) to 50% (Yugoslavia, Spain) of that of hard coal. India's reserves of solid fuels by major categories are shown in Exhibit 39. As only 22.6% of these reserves are of coking quality, the uses of India's coal resources may be somewhat limited.

EXHIBIT 39. INDIA'S RESERVES OF SOLID FUELS BY MAJOR CATEGORIES

<u>Category</u>	<u>Total Estimated Reserves</u>	<u>Percent</u>
Coking Coal	19,396	22.6
Non-Coking Coal	63,375	73.9
Tertiary Coal	902	1.1
Lignite	<u>2,100</u>	<u>2.4</u>
Total	85,773	100.0

Source: Bureau of Mines, International Coal Trade, vol. 45, No. 11, Nov. 1976.

- India. India's coal reserves, including lignite, are officially estimated at 86,000 million metric tons (equivalent to 418 billion barrels of oil), although there are indications that they may be as high as 131,000 million metric tons (639 billion barrels of oil). Two-thirds of these reserves are located in Bihar, West Bengal, and Madhya Pradesh in the northeast of India. The remaining reserves are unevenly distributed in different regions of the country except the northwest.

The Arab oil embargo and the resulting rise in oil prices has added an impetus to the revitalization of India's coal industry. Since the embargo production has increased at an annual rate of 12%, reaching 96.8 million metric tons in 1975. In fact, by 1976, stocks at the mines and major consumers were sufficiently high to cause concern about a surplus. As a result, Coal India Limited (CIL) has begun an active effort to increase exports over the 500,000 metric tons of 1975.

The major constraints on the export of large quantities of coal from India are the poor railroad system and port facilities for the transportation and loading of coal. However, improvements are being made in these areas. Indian railroads moved 14% more coal in 1975-1976 than in the previous 12-month period. Mechanized coal handling facilities are being developed at the ports of Vishakapatram, Haldra and Paradeep. The combined loading capacity of these ports will be 6.75 million metric tons per year. Plans call for the export of 2.5 million tons of coal by 1979.

India plans to invest \$309 million in the coal industry in 1976-77, an increase of 17% over 1975-76. Most of this will be used to purchase machinery for the modernization of coal mines.* Primary concerns now center, therefore, on the need to expand and upgrade track and rail car capacity.

- Korea. The government of the Republic of Korea has initiated programs to minimize the country's dependence on imported oil through the development of its coal resources. Included are plans for a complete survey of all coal fields.

Of reserves estimated at 1451 million metric tons, 545 million tons are recoverable using current mining technology. At present production rates, those revenues will be depleted in about 35 years.**

In 1975 production was 17.585 million tons (equivalent to 88 million barrels of crude oil). Plans have been made to increase production by 28% over the next five years (1977 through 1981) to 6060 million tons.

Although most coal is used to satisfy domestic needs, in 1973 221,000 tons were exported which was 1.6% of total production.*** Also, Korea is unique in that it uses substantial quantities of briquetted coal for home heating. This use is expected to decline gradually over time, as electrification and the rate of adoption of more Westernized home designs proceed. Thus, even with optimistic projections of coal utilization in the electric utility and industry sectors, it is likely that the amount of coal available for export will increase.

Through 1990 we project annual LDC coal production increases averaging 7% with the greatest contributions from the countries with annual per capita income below \$500. From 1990 to 2020 our projections for annual LDC coal production increases for the three world oil reserves cases are: high (oil exporters 2%, high importers 3%, middle importers 8%, low importers 7%), medium (exporters 3%, high importers 4%, middle importers 9%, low importers 7%), and low (exporters 3%, high importers 5%, middle importers 10%, low importers 8%).

Primary Electricity Production. Primary electricity includes only nuclear, hydropower, geothermal, and solar -- those sources of electricity other than

* Report 1975-76, Department of Coal, Ministry of Energy (New Delhi); FSD A-235 (New Delhi).

** ICT, Vol. 45, No. 1, Jan. 1976. Bureau of Mines, International Local Trade.

*** ICT, Vol. 45, No. 1, Jan. 1976.

generation by fossil fuels. This distinction prevents double counting of primary resources.

The growth rate of total electric energy is higher than that of primary electric energy. This disparity reflects an increasing gap between the total electric energy requirements of LDCs and the quantity available from hydropower. Exhibit 40 depicts these growth rates and the ratio of primary to total electric energy for 1970 and 1975. The proportion of primary electric energy to total electric energy has decreased by some 14% over that period. The largest single increase in primary electricity, $38.7 \text{ Gwh} \times 10^3$, occurred in Brazil as a consequence of massive hydroelectric development. Without that one country, the absolute increase in primary energy would have been only $30 \text{ Gwh} \times 10^3$, and the annual growth rate in primary electricity over this period 2.9% rather than 6.2%. (The increase in Brazil was accompanied by a very large effort in the construction of transmission systems.)

The production of nuclear energy on a commercial scale in the LDCs has occurred in only six countries. It accounts for only a small portion of the total electricity produced.

The production of electricity from geothermal sources in the LDCs is limited to $.5 \times 10^3 \text{ Gwh}$ in Mexico. Thus, the 1975 hydropower production, 249×10^3 , accounted for 94% of all LDC primary electricity.

Whether additional hydropower resources can be developed in any specific country depends on topography, the distribution of population centers and industries, estimated electric load growth, alternative investment opportunities, and other local characteristics. Of the more general concerns, most important is the availability of sites. Another is the relatively long gestation period of conventional hydroelectric facilities. This may be a significant deterrent to hydropower supply; if load increases at the planned growth rate of 11%, demand will double in 6.5 years. Requirements for irrigation or navigability may seriously limit the availability of this resource for electric generation. This would result in a seasonal variation in power availability, and possibly require investment in stand-by electric production facilities.

Following the pattern common to the exploitation of all natural resources, hydropower development to date has occurred at sites which are less costly to exploit and closer to load centers. The remaining sites are likely to be more difficult to develop and will require costly transmission systems connecting generating facilities with the points of use.

These arguments are not generally applicable to "mini-hydro," that is, small installations in the sub-megawatt range. Depending on local conditions, some hydropower production is likely to be available from installation of small low-head facilities supplying local villages, small industries and small agro-businesses, and not integrated into a national grid.

Increased primary electricity production is unlikely to offer a solution to planned rapid electrification in LDCs, at least under existing patterns of supply organization.

EXHIBIT 40. ELECTRICITY GROWTH IN LDCs

	10 ³ Gwh**						Ratio:	
	<u>Total Elec. Consumption**</u>			<u>Primary Elec. Production**</u>			<u>Primary Elec. Total Elec.</u>	
	1970	1974	Growth Rate %	1970	1975	Growth Rate %	1970	1975
Industrialized Countries								
Industrialized Countries	171.3	252.4	8.1	102.9	143.2	6.7	0.60	0.52
Balanced Growth Economies	38.0	61.1	9.5	22.1	25.3	2.7	0.57	0.30
Primary Exporters	109.4	137.5	4.7	53.0	70.3	5.8	0.48	0.49
Agricultural Countries	9.3	17.4	13.3	6.3	10.9	11.6	0.60	0.55
Current Oil Exports	25.9	34.	7.0	12.1	15.0	4.3	0.47	0.41
	354.7	502.4	9.1	196.4	264.7	6.2	0.55	0.48

* Gwh = Gigawatt - hour = 10³ Megawatt hours

Primary electricity includes hydropower, nuclear, geothermal and steam.

** 1974 total figure was first increased by the calculated growth rate to get a value for 1975.

This was then divided into the 1975 primary electricity figure.

Source: UN Yearbook of Industrial Statistics.

2.2.2 "Noncommercial" Energy

The importance of "noncommercial" energy in LDCs should not be underestimated. For example, in India, noncommercial fuels (dung, fuelwood, charcoal, and wastes) accounted for 58% of primary fuel consumption in 1970-71 (Exhibit 41).

Fuelwood is the most important and, with charcoal, the most desirable noncommercial fuel; its popularity is accounted for by its relatively low cost. In many areas the time expended in gathering fuelwood represents its only cost. Elsewhere, however, the scarcity and resultant high cost of fuelwood have led to the increased burning of dung and vegetable wastes which would normally be used as fertilizers. Few LDCs can afford such losses of nutrients and organic matter from their agricultural land.

Fuelwood is the primary fuel for as much as 90% of the population in many LDCs; the average user may burn one ton of this fuel per year.* In a number of LDCs, fuelwood comprises more than 90% of the total energy supply (e.g. Nepal, Tanzania, Nigeria, and Uganda).**

Fuelwood is the primary source for the domestic energy needed for food cooking, and in cooler regions, for home heating. This dependence has increased since the rise in the price of alternative fuels, such as kerosene, with the Arab oil embargo of 1973. Since it is used for such essential domestic purposes, the demand for fuelwood is relatively inelastic in LDCs.

Several industries also use wood as a source of energy, e.g., brickworks, distilleries, potteries, sugar works, tea factories, tile-works, and tobacco barns. It also provides steam for mechanical energy in sawmills, steam locomotives, and boats, and for the generation of electricity.

Fuelwood is usually the cheapest fuel available in LDCs, not only by weight but also by heat content. However, it is a bulky fuel that cannot be economically transported for more than a few hundred miles. This limits its uses to areas close to the source, unless it is first converted to a secondary fuel such as charcoal or methanol.

This problem in distributing fuelwood has resulted in local scarcities in many LDCs (e.g. Nepal, Korea, and India). In many population centers, the forest resource is being depleted, and fuelwood must be brought from increasing distances to provide for basic domestic needs.

Figures for the production and apparent consumption of fuelwood are shown in Exhibit 42. Production and consumption are usually the same for each country

* Erik Eckholm. The Other Energy Crisis: Firewood. Worldwatch Paper 1. Washington, D.C.: September 1975.

** D.E. Earl. Forest Energy and Economic Development. Oxford: Clarendon Press, 1976.

EXHIBIT 41. CONSUMPTION OF PRIMARY FUELS IN INDIA, 1970-71 (10^{15} BTU)

	<u>Consumption</u> <u>(10^{15} BTU)</u>	<u>Percent</u>
<u>Commercial</u>		
Coal	1.96	31
Oil	0.61	9
Hydropower	0.10	2
Subtotal	2.67	42
<u>Noncommercial</u>		
Dung	0.65	10
Firewood & Charcoal	2.34	37
Wastes	0.72	11
Subtotal	3.71	58
Total	6.38	100

Source: D.E. Carl, Forest Energy and Economic Development. Oxford: Clarendon Press, 1976.

EXHIBIT 42. PRODUCTION AND APPARENT CONSUMPTIONS OF FUELWOOD IN NON-OPEC LDCs
(x 10⁶ H³)

<u>Industrialized Countries</u>	<u>Production</u>	<u>Apparent Consumption</u>
Argentina	8.000	8.000
Brazil	140.000	140.000
Chile	3.000	3.000
Singapore	-	.007*
Rep. of Korea	7.350	7.350
Spain	4.623	5.057*
Taiwan	-	-
Uruguay	0.850	0.850
Yugoslavia	3.826	3.344*
	167.649	167.608
<u>Balanced Growth Economies</u>		
Colombia	20.00	20.00
Greece	2.090	2.094*
India	113.470	(74) 113.477*
Pakistan	8.468	8.468
Panama	1.400	1.400
Peru	5.700	5.700
Philippines	22.106	21.855*
Turkey	11.356	11.356
	184.590	184.350
<u>Primary Exporters</u>		
Botswana	-	-
Guinea	2.460	2.460
Guyana	0.010	0.010
Jamaica	0.001	0.001
Liberia	1.270	1.270
Mauritania	0.500	0.500
Morocco	2.480	2.480
Sierra Leone	2.500	2.500
Togo	1.250	1.250
Zaire	11.800	11.800
Zambia	4.550	4.550
	26.821	26.821

* 1974 Data.

EXHIBIT 42. PRODUCTION AND APPARENT CONSUMPTIONS OF FUELWOOD IN NON-OPEC LDCs (cont'd.)
(x 10⁶ H³)

<u>Agriculturally Oriented Economies</u>	<u>Production</u>	<u>Apparent Consumption</u>
<u>Agricultural Exporters</u>		
Costa Rica	2.130	2.130
Dominican Republic	1.850	1.850
Gambia	0.180	0.180
Guatemala	5.120	5.120
Honduras	3.000	3.000
Ivory Coast	4.885	4.885
Senegal	2.320	2.320
Sri Lanka	4.225	4.225
Thailand	16.440	16.440
	40.150	40.150
<u>Other Agricultural</u>		
Afghanistan	6.974	6.974
Bangladesh	15.821	15.821
Benin	2.000	2.000
Burma	18.559	18.559
Burundi	0.880	0.880
Cameroon	6.700	6.700
Central African Empire	1.600	1.600
Chad	3.110	3.110
Comoros	-	-
Cyprus	0.015	0.015
El Salvador	3.850	2.298*
Equatorial Guinea	0.370	0.370
Ethiopia	23.000	23.000
Fiji	0.007	0.007
Ghana	10.108	10.108
Haiti	3.750	3.750
Jordan	0.005	0.005
Kenya	10.875	10.875
Lebanon	0.060	0.060
Lesotho	-	-
Madagascar	4.870	4.870
Malawi	4.305	4.305
Mali	2.620	2.620
Mauritius	0.043	0.043
Mozambique	8.240	8.240
Nepal	8.700	8.700
Nicaragua	2.100	2.100

* 1974 Data.

EXHIBIT 42. PRODUCTION AND APPARENT CONSUMPTIONS OF FUELWOOD IN NON-OPEC LDCs (cont'd.)
(x 10⁶ H³)

<u>Agriculturally Oriented Economies</u>	<u>Production</u>	<u>Apparent Consumption</u>
<u>Other Agricultural (cont'd.)</u>		
Niger	2.320	2.320
Papau New Guinea	4.753	4.753
Paraguay	1.995	1.995
Rwanda	3.870	3.870
Somalia	3.000	3.000
Sudan	20.890	20.890
Surinam	0.005	0.005
Swaziland	-	-
Tanzania	32.965	32.965
Uganda	13.600	13.600
Upper Volta	3.920	3.920
Yemen Arab Republic	-	-
	<u>221.127</u>	<u>219.575</u>
<u>Current Oil Exporters</u>		
Angola	6.300	6.300
Bolivia	3.550	3.550
Brunei	0.074	0.074
Congo (PR)	1.310	1.310
Egypt	0.113	0.117*
Malaysia	5.499	5.371*
Mexico	8.170	(74) 8.441*
Oman	-	-
Syrian Arab Republic	0.050	0.050
Trinidad/Tobago	0.013	0.013
Tunisia	1.725	1.725
	<u>26.730</u>	<u>26.877</u>
Non-OPEC LDC Total	<u>667.067</u>	<u>667.381</u>

* 1974 Data.

Source: United Nations, World Energy Supplies 1971-1975. 1977.

since there is little export trade in fuelwood. Also, these figures represent minimum production, since the forest produce which is removed from privately owned land or illegally from forest reserves often remains unrecorded. In an extreme case, it was discovered that the recorded production of fuelwood and charcoal in mainland Tanzania for 1960 was less than 1.5% of the estimated consumption determined by survey.*

It is all but impossible to project the future consumption of fuelwood accurately, because many factors must be considered. Its availability will depend on whether sensible forestry practices are adopted in order to maximize production and prevent deforestation. Availability will affect the price of fuelwood relative to alternative fuels, which will also be a critical factor.

New sources of inexpensive energy may be developed which would compete with fuelwood and thus reduce its demand. At present the demand for fuelwood is relatively inelastic, and thus very dependent on population; hence population increases will also be important.

Two projections of fuelwood consumption for developing countries were made using data published by F.A.O. as presented by D.E. Earl. These data are shown in Exhibit 43. The low projection for the increase in fuelwood consumption was 11% for the decade 1975 to 1985. If this rate of increase is maintained, consumption will reach 1150 billion cubic meters by 2020. The high projection for fuelwood shows an increase of 24% for the decade 1970 to 1980, in addition to showing a higher level of initial consumption in developing nations (Latin America, Africa, and Asia Pacific). If this trend were to continue, the consumption of fuelwood will be 2,794 million cubic meters by 2020 (see Exhibit 44). The disparity seen in these projections illustrates the inadequacy of the data base regarding fuelwood.

In 1970 the growing stock (forest reserves) of developing countries was estimated to be 382 billion cubic meters. The annual forest increment (annual additions to reserves through photosynthesis) was placed at 9 billion cubic meters, of which one billion cubic meters per year (11%) were harvested for use as a fuel and in industry.**

Even if the high projection for fuelwood consumption ($2,794 \times 10^6 \text{ m}^3/\text{year}$ by 2020) were to be achieved, its demand could theoretically be met since it is

* K. Openshaw, Present Consumption and Future Requirements of Wood in Tanzania. Technical Report 3 FO SF/Tan 15. F.A.O., Rome: 1971:

** D.E. Earl.

EXHIBIT 43. LOW AND HIGH PROJECTIONS FOR FUELWOOD CONSUMPTION IN DEVELOPING COUNTRIES

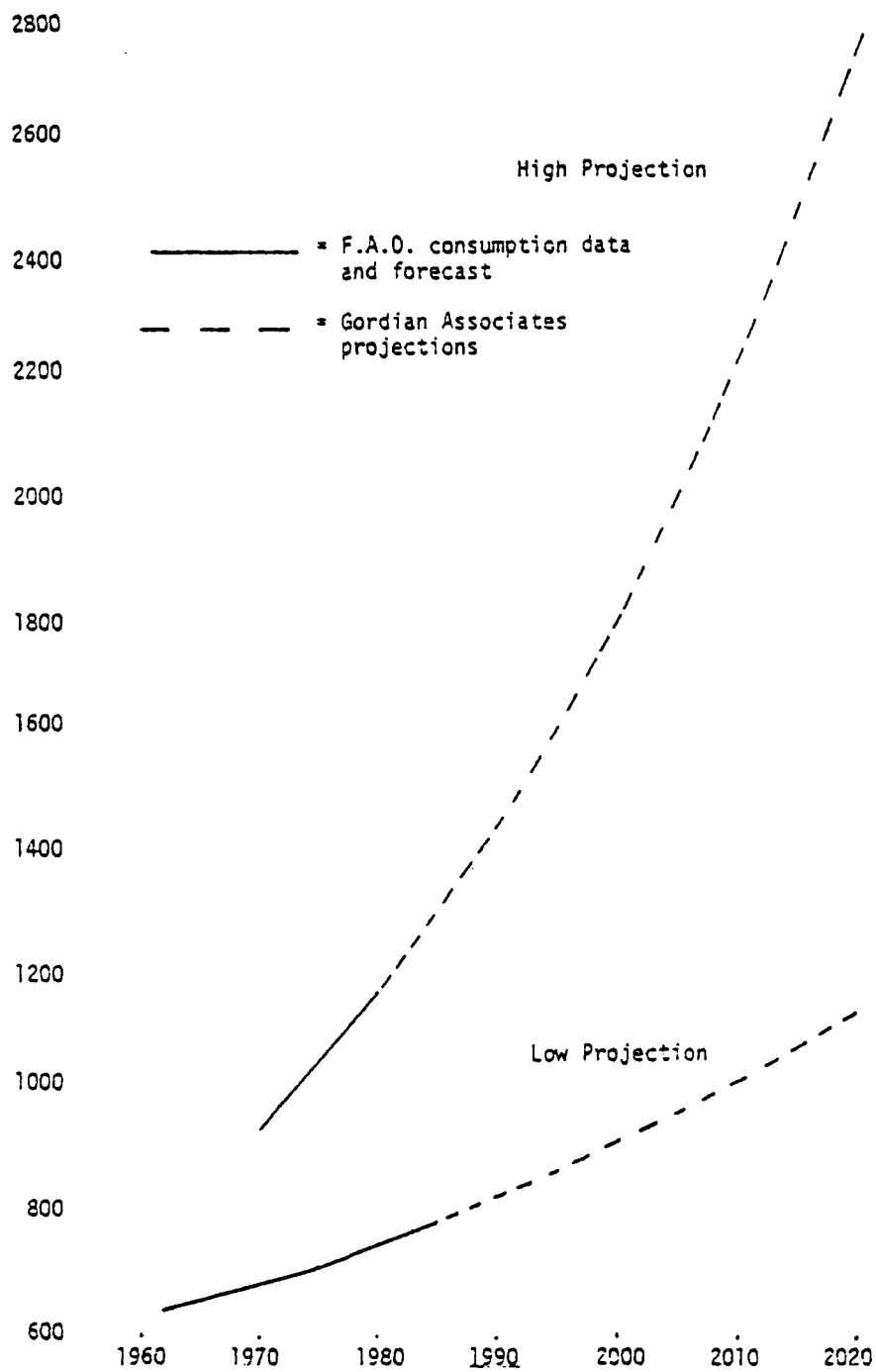


EXHIBIT 43. ESTIMATE OF FUELWOOD CONSUMPTION IN DEVELOPING COUNTRIES
(M³ X 10⁶)

Low Estimate

	<u>1962</u>	<u>1975</u>	<u>1985</u>	<u>% Increase for 1975-85</u>
Developing Countries	634	718	797	11

High Estimate

	<u>1970*</u>	<u>1980**</u>	<u>% Increase</u>
Latin America	223	244	9
Africa	255	312	22
Asia Pacific	475	626	32
Total	953	1182	24

* Yearbook of Forest Products. 1972 F.A.O., 1974.

** Agricultural Commodity Projections 1970-1980. F.A.O., 1977.

only 31% of the annual forest increment. However, it is unlikely that such levels of production would ever be achieved, since this demand could only be met by transporting large quantities of fuelwood for long distances. Even at the low consumption projection, problems of distribution would almost certainly inhibit production. All too often, in regions where the demand for fuelwood is high, deforestation has occurred or is occurring, and future production is jeopardized.

The extent to which the forest can be exploited as a source of energy in LDCs will depend on whether forest management programs can be rapidly and effectively introduced. The production of energy from the forest could be increased by the following methods: fuelwood plantations, refining and enrichment, and production of secondary forest fuels. These methods are discussed in Chapter 4.

3. LDC ENERGY FINANCING REQUIREMENTS AND PROSPECTS

As discussed above, the future stream of energy supplies, particularly hydrocarbons, is highly uncertain, not only at present real energy prices, but also at any other price level. Even if the non-OPEC LDCs as a group were to have enough economically recoverable reserves to be self-sufficient in energy through 2020, financing constraints will likely preclude this self-sufficiency. As a result, even in the "potential self-sufficiency" case (and certainly for less optimistic supply cases), the oil import burden on most non-oil-rich LDCs is likely to be so great that their savings rates and imports of other goods and services will decline. It is thus virtually certain that as currently inadequate investment levels decline further and as imports of needed productive capital goods must be curtailed, LDCs will experience lower growth. This economic malaise, which has impacted LDCs since 1973, will most likely continue through 2020.

3.1 FINANCING INDIGENOUS ENERGY EXPLORATION AND PRODUCTION

Energy development capital costs in non-OPEC LDCs through 2020 are projected to range from an average of \$5000 per new daily barrel of crude oil including exploration, development and transport, plus \$1800 per daily barrel for refining; to an average of \$37,000 for the generation, transmission, and distribution of electricity. Capital costs for energy-use equipment (for example, steam-raising boilers) are not included in this estimate. Exhibit 45 provides admittedly misleading precise point estimates for each energy type.

The methodology and results used to obtain the estimates of capital costs by each energy type are briefly summarized below.

- Crude Oil Development. Capital costs for crude oil exploration are influenced by a number of factors. We have explicitly estimated capital costs for the following factors: drilling cost per foot, average well depth drilled, offshore versus onshore drilling rates, find rates or other measures of drilling success, and flow rates of successful wells. Development and transportation costs can be estimated more directly. All the costs listed above vary by geographic area due to differences in the degree of past oil development. Thus, the levels of oil industry support facilities, services in the area, general infrastructure, and rates of inflation in area construction costs will also vary. The resulting estimated total costs by area are summarized in Exhibit 46. These include some portion of exploration and development costs which could be reasonably attributed to associated gas if and when gas gathering, processing, and transport

EXHIBIT 45. ESTIMATED INVESTMENT COST FOR NON-OPEC
LDC ENERGY EXPANSION, 1978-2020
(Per Incremental Daily Barrel Equivalents
in 1976 Dollars)

Crude Oil Exploration, Development and Transport	\$ 5,000
Refining	1,800
Natural Gas Inland Distribution*	2,700
Coal Exploration, Development, and Transport	5,000
All Electricity**	37,000
Primary Electricity	45,600
High BTU Coal Gasification	23,500
Oil Sands	30,000

* Exploration and development costs for associated gas are included in crude oil development costs. Costs for non-associated gas have not been estimated.

** Includes transmission system costs. See Exhibit 81 for a detailed breakdown by type of power plant.

Sources: Gordian estimates based on data from industry and agency sources, principally: World Energy Conference, 1977 Reports; International Petroleum Encyclopedia 1977; U.N. Petroleum Cooperation Among Developing Countries, 1977; CIA, Major Oil and Gas Fields of the Free World, January 1976 and June 1977; "Petroleum 2000," Oil and Gas Journal; August 1977, 1976-end International Review; API Basic Petroleum Data Book, June 1977; Joint Associations Survey of the U.S. Oil and Gas Producing Industry Annual; "When We'll Start Running Out of Oil," Fortune, October 1977; World Petroleum Report 1976, Maria Palmer Publishing Co., Inc.; World Oil, August 15, 1977 International Outlook Issue; various company annual reports; U.S. Department of Interior, Geological Survey; "Chart of Oil Wells Drilled vs. Size of Areas Favorable for Petroleum," February 1976; Petroleum Intelligence Weekly, various issues; Petroleum Economist, various issues; U.S. ERDA, Market Oriented Program Planning Study (MOPPS), June 1977; U.S. ERDA, LDC Nuclear Power Prospects, 1975-1990; U.S. International Trade Commission, Factors Affecting World Petroleum Prices to 1985; U.S. Department of Interior, Mineral Industry Surveys; American Gas Association, Gas Supply Review; United Nations, World Energy Supplies 1971-1975.

systems are installed. Such allocation would significantly lower the costs attributable to oil development.

- Refineries. Gordian estimates non-OPEC LDC refinery capital costs at \$1800 per daily barrel of capacity for a basic topping refinery of 3000 barrels per stream day. Economies of scale could reduce this cost to \$1600 at a capacity of 10,000 barrels per stream day. Hydroskimming could push this per barrel cost to \$2200 at a 10,000 barrel per day capacity.
- Natural Gas. Until recently, the high costs of gas transport have discouraged the development of gas supplies in many LDCs, unless relatively large consuming populations are located nearby. Capital exploration and development costs have been allocated to crude production until gas distribution systems come onstream to make it economical to produce already discovered gas and to drill for new gas. Inland gas transport and distribution capital costs are estimated at \$1600 per daily barrel equivalent capacity in North Africa and the mid-East, and up to \$3900 in Asia and the Far East.

EXHIBIT 46. AVERAGE NON-OPEC CAPITAL CRUDE DEVELOPMENT COSTS
(Total Costs Per Daily Barrel, 1976 \$)

Mexico	\$5,300
West Indies/Central America	5,000
South America	3,800
North Africa	3,300
Central/Southern Africa	5,900
Non-OPEC Middle East	3,300
Oceania	7,600
Asia/Far East	7,900

Source: Gordian Associates estimates.

EXHIBIT 47. ESTIMATED NON-OPEC LDC CAPITAL COSTS 1978-1990: ELECTRICITY (1976 DOLLARS)

	<u>Generation Capital Costs</u>			<u>Transmission</u>	<u>Distribution</u>	<u>TOTAL, Generation- Distribution</u>
	<u>\$/Kw capacity</u>	<u>capacity factor</u>	<u>\$/daily bbl equivalent</u>	<u>\$/daily bbl equivalent</u>	<u>\$/daily bbl equivalent</u>	<u>\$/daily bbl equivalent</u>
1. Gas-fired boiler	330	.65	11,600	1,000	10,000	22,600
2. Resid. fired gas turbine	170	.30	12,900	1,000	10,000	23,900
3. Oil-fired boiler	500	.65	17,500	1,000	10,000	28,500
4. Coal, no desulfurization	600	.65	21,000	6,000	10,000	37,000
5. Coal, flue gas desulfurization	710	.65	25,000	5,000	10,000	40,000
6. Nuclear, light water	680	.65	23,800	7,000	10,000	40,800
7. Hydropower	600	.50	27,600	8,000	10,000	45,600
8. Nuclear, high temp gas	850	.65	29,800	7,000	10,000	46,800
9. Nuclear, heavy water	1,100	.65	38,500	7,000	10,000	55,500

- Assumptions:
- 1 million metric tons of oil (7.33 million barrels) produces 4 billion Kwh electricity in a new plant.
 - In a day, that would be equal to 167 million Kw capacity for 24 hours, or 23 Kw capacity per daily barrel. At 65% capacity factor, 257 million Kw or 35 Kw capacity per daily barrel; at 50% capacity factor, 334 million Kw or 46 Kw capacity per daily barrel; at 30% capacity factor, 560 million Kw or 76 Kw capacity per daily barrel.
 - Transport costs minimal for gas and oil fired thermal capacity but greater for other fuels because of siting constraints, which can be expected to become more severe.
 - Distribution costs similar for all primary sources.
 - All costs assume 10% interest during construction.
 - Coal fired generation costs assume widespread diseconomies of scale, e.g., 200 MWe plants built instead of 800 MWe plants -- with resulting 30% higher unit capacity costs.

EXHIBIT 48. ESTIMATED NON-OPEC LDC CAPITAL COSTS:
COAL DEVELOPMENT (1976 DOLLARS)

	Exploration	Mining		Total Exploration and Development		Inland Transport		Total Capital Costs
	(\$/annual metric ton capacity)	(\$/annual metric ton capacity)	Capacity factor	(\$/annual metric ton capacity)	(\$/daily bbl equiv.)	(\$/annual metric ton capacity)	(\$/daily bbl equiv.)	(\$/daily bbl equivalent)
Strip Mines	4	16	.90	22	1600	24	1800	3400
Deep Mines	4	36	.70	57	4200	24	1800	6000

Coal Development Capital Cost Assumptions:

1. a. \$36 per annual metric ton capacity average deep and strip.
1. b. \$40 per annual metric ton capacity underground mines; \$20 strip mines.
2. 1 metric ton coal = about 0.67 ton oil = 5 barrels oil.
3. 1 metric ton lique = about 0.2 ton oil = 1.5 bbls oil.
4. \$24 per annual metric ton inland transport capacity.
5. 1 barrel oil = 0.2 metric ton coal.
6. 70% capacity factor for deep mines.
7. 90% capacity factor for strip mines.

Source: Gordian Associates estimates.

EXHIBIT 49. TOTAL CAPITAL INVESTMENT REQUIRED FOR
LDC NET ENERGY SELF-SUFFICIENCY BY 2020
(Million Barrels Oil Equivalent Per Day)

INCREASING REAL ENERGY PRICES CASE

	<u>Oil</u>		<u>Coal</u>	<u>Gas</u>	<u>Primary Electric</u>	<u>TOTAL</u>
	<u>Production</u>	<u>Refining</u>				
2020 Demand	27.9	27.9	19.1	3.5	4.6	
1975 Capacity	<u>3.9</u>	<u>11.0</u>	<u>2.4</u>	<u>0.4</u>	<u>1.4</u>	
Additional Capacity Required	24	16.9	16.7	3.1	3.2	
Investment Required (billion 1976 dollars)	\$120	\$30.4	\$83.5	\$8.4	\$144	\$326.3

CONSTANT REAL ENERGY PRICES CASE

	<u>Oil</u>		<u>Coal</u>	<u>Gas</u>	<u>Primary Electric</u>	<u>TOTAL</u>
	<u>Production</u>	<u>Refining</u>				
2020 Demand	56.6	56.6	38.1	9.9	8.5	
1975 Capacity	<u>3.9</u>	<u>11.0</u>	<u>2.4</u>	<u>0.4</u>	<u>1.4</u>	
Additional Capacity Required	52.7	45.6	35.7	9.5	7.1	
Investment Required (billion 1976 dollars)	\$263.5	\$82.0	\$178.5	\$25.6	\$319.5	\$869.1

- Electricity. Electricity capital costs per daily barrel of crude equivalent are expected to range from \$22,600 for a gas-fired boiler to \$55,500 for a heavy water nuclear plant during the period 1978-1990. The generation costs in Exhibit 47 are derived from present \$/Kw capacity figures and are adjusted for varying capacity factors. Transmission and distribution costs are greater than the newly revised World Bank estimates because it is expected that environmental and other concerns will increasingly inhibit site selection in LDCs, and that distribution capital cost escalation has been underestimated. All costs assume 10% interest during construction. Coal-fired generation costs assume construction of smaller than optimum-scale plants (roughly 800 MWe per plant) and erection costs higher than in developed countries. This results in LDC capital costs per daily barrel equivalent roughly 23% above those in the U.S.
- Coal. As shown in Exhibit 48, total LDC coal production capital costs are projected to be \$3400 per daily barrel crude equivalent for strip mined coal and \$6000 for deep mined coal. This assumes a 70% capacity factor for deep mines and 90% for strip mines, with \$24 per annual metric ton for inland transport capacity. Exploration costs are expected to be about \$4 per annual metric ton of capacity during the period.

Based on these estimates, an aggregate investment of approximately \$386.3 billion, or \$9.7 billion per year (presuming such investments are spread over the period 1978-2018) would be required to achieve self-sufficiency in the "increasing real energy prices," and \$869.1 billion, or \$21.7 billion per year in the "constant real energy prices case." Both estimates are presented in Exhibit 49.

3.2 AVAILABILITY OF ENERGY DEVELOPMENT INVESTMENT CAPITAL

Access to the sources of financing for energy resource exploration and development will vary depending upon the type of energy, the characteristics of an individual LDC, and other factors. The energy financing sources include: domestic savings, international private capital markets, official international development financing, and private companies' equity investment.

Maximum oil exploration, development, and refining can be financed either directly or through private risk investment (although there is evidence that oil companies, with more exploration opportunities than they can finance, will bypass some countries due to fear of expropriation, inability to negotiate mutually acceptable terms, etc.). Coal, hydropower, and natural gas will have to be financed predominantly from the domestic savings and/or net external capital flows of individual LDCs themselves. Unfortunately, there is a lack of coincidence between the countries where known energy resources are located and those which seem likely to be able to finance additional energy resource development based on their present available net financing and rates of GNP growth.

3.2.1 LDC Investment Climate

Because most private investment in LDC energy is in petroleum, this area provides the best example of the impact of an LDC's perceived investment climate on its energy development. LDCs with favorable petroleum prospective acreage and minimal indigenous exploration and development technology will likely have to maintain favorable petroleum investment policies in order to attract adequate capital and the best available technology. In effect, this will probably mean offering high-technology foreign companies assurances of: (1) security of access to crude discovered, (2) adequate return on capital investment relative to other alternatives, and (3) security of a per-barrel net operating margin more favorable than present OPEC per-barrel margins, which currently range from about 20¢ to more than \$1.00 plus transportation.

Only if an LDC were fortunate enough to discover very large oil reserves (and development proved relatively inexpensive), then perhaps the per-barrel net operating margins made available to foreign companies could be reduced to approximately the per-barrel margins available in some giant fields in the Middle East, which are currently 20¢ to 40¢ plus transportation. More expensive development and less large reserves might require per-barrel margins in the 80¢ to \$1.00 range, as in Gabon, Ecuador, or Indonesia. But compensation for increased risk (e.g., absence of long term trade history and proven stability of agreements once negotiated) may require an LDC to offer a potential per-barrel return somewhat greater than the OPEC margins. Even in the case of OPEC countries with mature petroleum development, some have had to back off from crack-downs on company margins.

Only countries with extensive oil development expertise, such as Mexico, are likely to be able to depart from this pattern. Elements of Mexico's, Angola's, and Egypt's LDC oil development policies relevant to company investment deliberations are discussed in Section 5.5.

In addition to Egypt, a number of LDCs who had previously nationalized their oil industries have recently found it in their interests to reinvoke foreign oil company participation in oil development. Aspects of recent agreements of more than 20 countries are listed below in Exhibit 50.

EXHIBIT 50. ASPECTS OF SOME RECENT LDC AGREEMENTS WITH FOREIGN COMPANIES

<u>Country</u>	<u>Terms</u>	<u>Companies</u>
Brazil	Reversed 22-year state oil monopoly policy to attract foreign companies to explore unexplored areas under risk contracts	BP Elf/AGIP Eensearch Exxon

EXHIBIT 50. ASPECTS OF SOME RECENT LDC AGREEMENTS WITH FOREIGN COMPANIES (cont'd.)

<u>Country</u>	<u>Terms</u>	<u>Companies</u>
Chile	Reversed state oil monopoly policy, opened seven offshore and onshore areas to foreign participation, but initial stringent terms discouraged any takers.	
Peru	Relaxed stringent model contract terms to lure back oil companies who had abandoned operations.	
Egypt	Traditional concessions.	BP, Amoco, Socal, Texaco, Exxon, Shell, Conoco AGIP, Marathon, Mobil, Gulf, Deminex
Tunisia	Traditional concessions.	Elf/Aquitaine
Morocco	Minor participation concessions.	Exxon, Sun, Phillips
Zaire	Traditional concessions.	Shell, Petrofina, Amoco
Cameroon	Traditional concessions	Mobil, Shell, Gulf
Oman	Production sharing	Shell, Elf/Aquitaine
Malaysia	Production sharing: maximum cost recovery of 20% for oil and 25% for gas; royalty of 10% to government. Remainder of oil or gas 70% to state oil company, 30% to companies. Companies pay 45% income tax. Above a \$12.72 first year base price, plus 5% per year, 70% of oil profit proceeds must be refunded.	Shell, numerous companies
Argentina	Reversed state oil monopoly policy to attract back foreign oil companies.	
Greenland	Danish government gets 50% carried interest plus 12.5% royalty interest plus 55% tax on any net profits. Government gets 80% of oil from any commercial discovery.	Atlantic Richfield, Cities Service, Hispanoil, Hubbay, Amoco, Mobil, Deminex Pan Canadian
Trinidad/Tobago	Government has 15-25% equity in all blocks awarded since 1974.	Amoco, Texaco, Tesoro

EXHIBIT 50. ASPECTS OF SOME RECENT LDC AGREEMENTS WITH FOREIGN COMPANIES (cont'd.)

<u>Country</u>	<u>Terms</u>	<u>Companies</u>
Guatemala	Traditional concessions.	Elf Aquitaine
Nicaragua	Traditional concessions.	Occidental
Belize	Traditional concessions.	Exxon, Canadian Superior
Netherlands Antilles	Production sharing; if commercial discovery, producers can take up to 40% of annual production to recover exploration and operating costs.	Marathon, Amerada Hess, Getty, AGIP Phillips, Hispanoil
Costa Rica	Drilling stopped after government nationalized crude and product operations.	
El Salvador	Asked for U.S. and Canadian consulting help to establish prospective regulations after no companies met stringent state concession requirements.	
Colombia	Opened new offshore and onshore areas for exploration via 60-40% production sharing requirements.	BP, Aquitaine, Intercol, Phillips
Bolivia	Production sharing controls.	16 companies Occidental, Tesoro
Greece	Government gets 65% of oil produced.	Wintershall, Dennison Mines Hellenic Oil

3.2.2 Availability of Development Capital by Fuel Type

The prospects for developing each fuel type are summarized below by LDC income group. As much of the data for this section is available only by income group categories, they were employed here. This analysis addresses only high, middle, and low income oil importing companies. Oil exporters are assumed to have sufficient access to capital to be able to finance the development of all their reserves. Exhibit 51 provides a matrix which shows the coincidence between country groups used elsewhere in the report and the income categories of this section with oil exporters, industrial and balanced growth countries concentrated in the high income group, and primary exporters and agriculturally oriented economies mainly in the middle and low income range.

EXHIBIT 51. CORRESPONDENCE BETWEEN COUNTRY CATEGORIES AND INCOME GROUPS

	<u>Industrialized Countries</u>	<u>Balanced Growth Economies</u>	<u>Primary Exporters</u>	<u>Agriculturally Oriented Economies</u>	<u>Current Oil Exporters</u>
<u>High</u>	Argentina Brazil Chile Rep. of Korea Singapore Spain Taiwan Uruguay Yugoslavia	Colombia Greece Panama Peru Turkey	Guyana Jamaica Zambia	Costa Rica Cyprus Dominican Republic Guatemala Lebanon Mauritius Nicaragua Paraguay Surinam	Angola Brunei Malaysia Mexico Oman Syrian Arab Rep. Trinidad / Tobago Tunisia
<u>Medium</u>		Philippines	Botswana Liberia Mauritania Morocco Togo	Cameroon Cen. Afr. Empire Comoros El Salvador Eq. Guinea Ghana Honduras Ivory Coast Jordan	Kenya Mozambique Papua New Guinea Senegal Sudan Swaziland Thailand Uganda Yemen Arab Rep.
<u>Low</u>		India Pakistan	Guinea Sierra Leone Zaire	Afghanistan Bangladesh Benin Burma Bermuda Burundi Chad Ethiopia Gambia Haiti	Lesotho Madagascar Malawi Mali Nepal Niger Rwanda Somalia Sri Lanka Tanzania Upper Volta

- Natural Gas. About 31% of natural gas reserves in oil importing LDCs are associated with oil reserves. These can be readily financed, if in no other way than by making this a condition of private company participation in oil reserves development. For the remaining 69 percent, the following apply in general terms:
 - Most reserves are located in countries with relatively good access to private capital markets.
 - Most reserves are located in countries with below-average growth of financing ability.
 - Financing is long-term in nature but generally can be self-liquidating.
 - Capital intensity is moderate.
 - Foreign exchange intensity of development is relatively high.
 - Financing requirements can be reduced by selling gas cheaply and encouraging users to locate closer to supply sources. This often requires a climate acceptable to foreign equity investors.

The following estimated impacts are specific to high, middle and low income LDCs.

	<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Total</u>
Reserves where there is access to capital markets (%)	92.8	100	64.3	78.4
Reserves in countries with about average GNP growth (%)	30	100	0.2	20.1

Based on the above, we estimate the following percentages of non-associated gas which can be financed in oil importing LDCs to be:

<u>High</u>	<u>Middle</u>	<u>Low</u>
97	94	80

Adjusting for associated gas, the percentages of all gas which can be financed are:

<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Weighted Average</u>
98	96	86	92

- Hydropower. The financing of hydropower development is affected by the following:
 - Only a small share of LDCs' financial resources is located in countries with hydropower reserves.
 - Many of the LDCs reserves are located where capital market access is poor.
 - On the other hand, the World Bank historically has given priority to hydropower development in allocating its funds. In 1976 close to \$1 billion was allocated for electric power, of which hydropower generation and distribution were the major components, versus relatively insignificant funding for other energy development.
 - Many of the hydropower reserves are located where GNP growth is above average.
 - Financing is long-term and often not self-liquidating. Some of the benefits of hydropower are in the nature of social overhead capital and are not market related. Also, in most LDCs, electricity prices are heavily subsidized, thus precluding the recapture of capital costs.
 - Capital intensity is extremely high, but capital costs vary constantly among projects.
 - Foreign exchange intensity is moderate.

The following impacts are specific to high, middle or low income LDCs:

	<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Total</u>
Reserves where there is access to capital market (%)	96.9	31.4	32.0	60.0
Reserves in countries with above average GNP growth rate (%)	67.2	27.9	58.5	61.2

Overall, we estimate that the following percentages of hydropower can be financed:

<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Weighted Average</u>
90	60	60	73

● Coal. The financing of coal development is affected by the following:

- A disproportionate share of coal reserves are in India and Korea, which have had relatively good access to capital marketing.
- Capital intensity is low for coal mining but high for coal transportation and utilization.
- Foreign exchange intensity is low for coal mining and moderate for coal utilization.
- The allocation of scarce financial resources to coal development has historically been limited to domestic requirements. Despite prospects for some exports from India or Korea, LDC international trade in coal is likely to remain low. As a result, international private equity is not likely to be a serious financing option.
- Potential resources are more widely dispersed than proven reserves, and many countries have engaged in little coal exploration to date.

The following impacts are specific for high, middle or low income LDCs:

	<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Total</u>
Reserves where there is access to capital market (%)	43.8	18.1	91.4	71.3
Reserves in countries with above average GNP growth (%)	84.7	100.0	3.1	39.2

We estimate the following percentages of coal which can be financed:

<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Weighted Average</u>
80	75	50	62

To summarize, we estimate that oil importing LDCs would be able to finance the following percentages of their energy resources, expressed as a percent of the total potentially exploitable resources:

	<u>High</u>	<u>Middle</u>	<u>Low</u>	<u>Weighted Average</u>
Oil	100%	100%	100%	100%
Natural Gas	98%	96%	86%	92%
Hydropower	90%	60%	60%	73%
Coal	80%	75%	50%	62%

Due to financing constraints, these estimates translate into percentage shortfalls in indigenous LDC energy supply. Applying these percentage shortfalls to the self-sufficiency financing requirements estimated in Exhibit 49, the total financing shortfall for the "increasing real energy prices case" is estimated to be \$77.3 billion, and to be \$156.0 billion in the "constant real energy prices case." As shown in Exhibit 52, these amounts, which equate to annual financing shortfalls of approximately \$1.9 billion and \$3.9 billion respectively, (over a 40-year period) are primarily for coal and primary electric power development.

These estimated shortfalls will be influenced by a number of factors. For example, the continued easy availability of substantial developed country financing for LDC nuclear power plants (which to date have been financed on extremely generous terms) was not assumed in our estimates. Any changes in LDC terms of trade will have a major impact on the actual financing shortfall. Finally, and perhaps most important, increases in the levels of development assistance provided by the developed countries and oil exporters could erase any such deficits. In 1976 the difference between OECD Development Assistance Committee estimates of actual assistance and the UN target of 0.7% of GNP (which only three countries -- Sweden, Norway, and the Netherlands -- currently meet) was over \$14 billion. Through vehicles such as the Arab Petroleum Investment Corporation's increased oil exporter financing, either as development assistance or as business ventures, financing could potentially equal or exceed this amount.

3.3 PROJECTED LDC OIL IMPORT FINANCING BURDEN

Even if the non-OPEC LDCs as a group were to achieve an aggregate supply of commercial primary energy equal to their aggregate demand for such energy, most LDCs would still be net importers of energy (almost entirely oil), and would still face a substantial import financing burden. The number of countries affected and the severity of the situation rapidly increase as less optimistic supply scenarios are presumed. In fact, the general economic prospects gap between oil exporters (who regardless of whether they join OPEC, are likely to cooperate with OPEC under all but the most optimistic supply assumptions) and oil importing LDCs is likely to widen.

Obviously, we cannot predict what countries will be oil exporters or how much they will export in 1990 and 2020. However, based on present trends in the rates of LDC oil exports to total production, and exports to total GNP, we believe that it is reasonable under this scenario to postulate that 35% of total LDC oil production* will be exported by countries representing 20% of total LDC GNPs in 1990 and 25% in 2020. Exhibit 53 shows the oil import bill under the two cases described in Section 2.1.

* The OECD World Energy Outlook projects an export percentage of close to 50% of non-OPEC LDC production in 1985.

EXHIBIT 52. FINANCING SHORTFALL

Increasing Real Energy Prices Case

<u>Energy Source</u>	<u>Total Financing Requirement</u> (billions)	<u>Percentage Shortfall</u>	<u>Dollar Shortfall</u> (millions)
Oil	\$120	0	0
Coal	\$ 83.5	38%	\$31.7
Natural Gas	\$ 8.4	8%	\$ 6.72
Primary Electricity	\$144	27%	<u>\$38.9</u>

Total Shortfall = \$77.32 billion

Constant Real Energy Prices Case

	<u>Total Financing Requirement</u> (billions)	<u>Percentage Shortfall</u>	<u>Dollar Shortfall</u> (millions)
Oil	\$263.5	0	0
Coal	\$178.5	38%	\$67.83
Natural Gas	\$ 25.6	8%	\$ 2.05
Primary Electricity	\$319.5	27%	<u>\$86.27</u>

Total Shortfall = \$156.15 billion

It is noteworthy that the projected absolute oil financing burden is approximately equal in both cases, despite very different consumption levels in 2020. Oil import costs would represent 1.9% of the GNP of oil importing LDCs in 1990, and 2.5% of GNP in 2020 for the "increasing real energy prices case." This represents 13-17% of real capital formation for most LDCs.

Unfortunately, the self-sufficiency case is unduly optimistic. At a minimum, the additional oil imports required to offset the shortfall in indigenous LDC energy supplies due to financing constraints must be taken into account.

Applying the shortfall percentages calculated in the preceding section to projected 1990 and 2020 oil importers' production yields additional oil import requirements of 2.6 MMBDOE and 8.9 MMBDOE, respectively, in the "increasing real energy prices case," and 2.7 MMBDOE and 17.6 MMBDOE for the same years in the "constant real energy prices case."

These additional oil imports can be entirely attributed to LDCs' financial inability to exploit their indigenous energy resources. The additional financial burdens they create are summarized below, in billions of 1976 dollars:

	<u>1990</u>	<u>2020</u>
Increasing Real Energy Prices Case	\$12.3	\$84.5 (@ \$26 per barrel)
Constant Real Energy Prices Case	\$12.8	\$83.5

In the two cases, these represent an additional 2.3% and 1.5% of GNP in 2020. Aside from the point that the additional oil import burden far outweighs the additional annual energy development financing requirement to eliminate such imports, the total impact on the oil importing LDCs now represents 20% or more of real net capital formation. Even assuming a very loose relationship between investment and economic development, this will lead to a dramatic slowdown in growth for the oil importing LDCs. To the extent that demand is constrained by higher real prices, which compensate for reduced consumptions, conclusions as to financing burdens remain substantially unchanged under either high or low demand estimates.

EXHIBIT 53. NON-OPEC LDC OIL IMPORT BILL

	<u>Oil*</u> <u>Consumption</u>	<u>Percent</u> <u>Imports</u>	<u>Delivered</u> <u>Price**</u>	<u>Oil Import</u> <u>Bill (10⁹)</u>	<u>% of Oil</u> <u>Importing</u> <u>LDCs GNP</u>
Increasing Real Energy Prices Case					
1990	11290	35%	\$13***	\$18.8	1.9
2020	27927	35%	\$26	\$92.8	2.5
Constant Real Energy Prices Case					
1990	12015	35%	\$13	\$19.9	1.8
2020	56607	35%	\$13	\$94.0	1.6

* 10³ BPD OE.

** Per Barrel.

*** See price assumptions in Section 2.1.

4. ALTERNATIVE LDC RESPONSES TO THE ENERGY SITUATION

The energy policy options available to LDC decision makers are constrained by the range of scarcities which constitute "underdevelopment." Since 1973 energy has become one of the most uniformly acute constraints on economic development; all current and potential development paths must thus be evaluated regarding their impact on energy consumption.

The effects of energy scarcity on the economic development of LDCs are broad-based because:

- . Energy is required for virtually all forms of production and distribution, and energy byproducts (e.g. fertilizers) are vital to agricultural production.
- . The level of energy consumption is directly related to the level of overall economic activity; growth thus requires energy.
- . Energy use is correlated with modernizing and structural change, including urbanization, industrialization, modern agriculture, transport, and infrastructure.
- . Most LDCs rely heavily on imported oil; the failure to set and meet their domestic energy conservation targets manifests itself as a balance of payments financing shortage, which may lead to a variety of unattractive financial repercussions. These include the inability to import capital equipment, a draining of foreign exchange reserves, the growth of debt and debt-financing burdens, currency depreciation, and, ultimately, loss of international credit standing. In general, the final equilibrium mechanism is the reduction of energy consumption by the starving of real economic growth, either directly through a reduction in investment or indirectly through measures such as those which the IMF normally imposes in return for use of the "Witteveen Facility" or other emergency credit sources.

The status quo scenario presented in Chapter 2 is based on the assumption that in the aggregate, past development trends will continue and thus, the extrapolation of past energy-income relationships is valid. In fact, given the immense impact of the energy financing burden on many LDCs, it is likely that some or all of them will adopt strategies to respond to the situation.

A number of alternatives are available to LDCs desiring to maintain or improve their growth rates, to improve the distribution of the benefits of such growth, or to accomplish other social or economic objectives within the constraints imposed by the quadrupling of oil prices since 1973. These options include:

- . energy conservation within the major energy consuming sectors;
- . intersectoral shifts in investment and growth in order to emphasize less energy-consumptive sectors;
- . more intensive development of traditional, indigenous commercial or noncommercial energy resources;
- . development and/or adoption of new energy supply technologies for renewable energy sources;
- . limitations on domestic consumption (to maintain previous rates of domestic savings) and/or imports (to preserve foreign exchange);
- . generation of more exports and therefore more foreign exchange to pay for the increased cost of energy imports;
- . more equitable distribution of the benefits of whatever growth level is achieved, in order to assure that everyone realizes at least some basic level of human well-being; and
- . greater regional LDC energy and/or economic cooperation.

In addition to these options, another strategy -- increased financial transfers from developed and/or oil exporting countries to oil importing LDCs -- must play an important role in averting serious energy-induced declines in LDC development rates and in providing a minimum level of economic well-being for all of the world's citizens.

4.1 ENERGY CONSERVATION AND FUEL-SWITCHING

Economic growth and development imply changes in the composition of an LDCs output in terms of both the sectoral balance of production and intra-sectoral shifts (from handicraft to industrial manufacture, for example). These changes typically lead to greater overall energy intensity in production and to the increased utilization of commercial as opposed to non-commercial fuels.

Historical and projected income elasticities show a nearly one to one relationship between income growth and energy consumption. Rising GNP (and GNP per capita) had led to more energy intensive economic activity in most LDCs. The characteristic production shifts which increase energy use include: the growth of industry, urban migration, and modern transportation development. Even agriculture, which is less energy intensive than industry, has come to

rely increasingly on energy inputs through the use of fertilizer, tractors, and irrigation systems. In addition to increasing energy demand, these production shifts imply an even greater increase in the use of commercial energy.

Similarly, changes in lifestyle can also increase energy demand. This is particularly so for the changes associated with middle and upper income status and with "Westernization": private motorized transport, electric appliances, etc.

A simple example of the impact of production shifts is afforded by Pakistan. Data on the 1971 sectoral distribution of GDP and of energy consumption are provided in Exhibit 53, revealing a much greater energy intensity in industry than in her other two sectors. Clearly, in this case, shifts in the sectoral balance can significantly affect energy consumption. As in many other LDCs, the actual sectoral growth rates in Pakistan during 1971-72 (7% for industry, 2.3% for agriculture, and 4% for services) implied an increasing share for industry in the national income.

EXHIBIT 54. ENERGY CONSUMPTION BY SECTOR IN PAKISTAN*

	<u>Industry</u>	<u>Agriculture</u>	<u>Services</u>
(1) Percent Distribution of GDP	21	42	37
(2) Percent of Energy Consumption	52	11	37
(3) Relative Energy Intensity (Ratio of (2) ÷ (1))	2.48	.26	1.0

* 1971 Data.

It cannot be supposed that countries can, or should, alter their development priorities for energy conservation, except in order to prevent an energy scarcity from constraining their development. In many LDCs rural electrification remains a fundamental objective of socio-economic development. Exhibit 55 shows regional electricity consumption in the Ivory Coast. The Abidjan area, with only 21% of the population, consumes 60% of the total electricity generated. Despite the fact that 67% of this country's electricity is generated by imported petroleum, the Government of the Ivory Coast has pursued an aggressive

EXHIBIT 55. THE CONSUMPTION OF ELECTRICITY IN THE IVORY COAST
(HV: High Voltage, LV: Low Voltage)

<u>Gwh</u>	<u>Abidjan</u>			<u>Other Towns</u>			<u>Total</u>		
YEARS	HV	LV	Total	HV	LV	Total	HV	LV	Total
1970	186	161	347	39	43	82	225	204	429
1971	208	169	377	62	52	114	270	221	491
1972	235	191	426	76	62	138	311	253	564
1973	269	217	486	90	85	175	359	302	661
1974	278	221	499	104	75	179	382	296	678
1975	302	248	550	138	102	240	440	350	790
1976	333	253	586	182	223	405	515	375	890

Source: La Cote d' Ivoire en Chiffres, 1977-78.

electrification program to improve living standards and social amenities, as is shown by Exhibit 56. In fact, one of the "Five Strategic Policy Objectives" of the 1976-1980 energy plan seeks to:

"Improve the quality of human life (through) a program to introduce electricity into the maximum number of urban and rural households; subsidy through rate policy -- for low income subscribers and the execution of a search program for low price electrical appliances which could be more widely afforded by the public than the ones presently distributed..."*

It is impossible to generalize about the LDCs' current structures since they vary so widely among individual countries. "Average" structures for the categories of LDCs addressed in the next chapter are presented in Exhibit 57.

* "Ivory Coast: The Energy Situation and Perspectives." Paper presented to the United Nations Ad Hoc Group of Experts on Energy Planning in Developing Countries, December 1977.

EXHIBIT 56. CHANGES IN THE RATIO OF ELECTRICITY CONSUMPTION IN ABIDJAN TO
ELECTRICITY CONSUMPTION IN THE REST OF THE IVORY COAST

1960	10.40
1965	6.27
1970	4.23
1971	3.30
1972	3.09
1973	2.78
1974	2.79
1975	2.29
1976	1.45

Source: La Cote d' Ivoire en Chiffres, 1977.

In view of the high degree of variation among countries within each category (especially the oil exporter and balanced growth categories), these "averages" should be interpreted with care. However, they generally reflect the differences in sectoral emphasis and socio-economic status among the various groups.* The major points extracted from the analysis of individual countries include the importance of agriculture even in the most highly industrialized LDCs, and at the other extreme, virtually the complete absence of any "modern" industry in many agricultural economies, particularly in Africa. Also, there is a clear and direct relationship between the level of industrialization and both income per capita and relative equality of income distribution.

Exhibit 58 portrays the range of commercial energy intensities** between sectors for three relatively highly industrialized developing nations. The inter-country and inter-sector range would presumably be much greater if other, less highly developed countries were included. However, even these

* The oil exporters and balanced growth economies are so disparate that the "average" numbers for these groups have little meaning.

** Unfortunately, the data is expressed in terms of energy values rather than physical quantities, so some of the variation in "energy intensities" is presumably due to differing energy pricing policies among countries and between sectors.

EXHIBIT 57. BASIC SOCIAL AND ECONOMIC INDICATORS - MEAN FIGURES (BY GROUP)

Groups	GNP Per Capita 1974 U.S.A.	Urbanization (1975)	Commercial Energy Consumption Per Capita (1975) (kgce)	Crude Death Rate (per 1,000) (1975)	Infant Mortality Rate (per 1,000) (1970)	Life Expec- tancy (1975)	% Income Received by Low- est 20% (1975)	% Income Received by High- est 5% (1975)	% Mnfg. Value (In Pro- ducers Values) to GNP	Export % of GNP	Arable Land (sq. mi. 10-3) Per Capita
Industrialized Countries	1120	57	1220	8	62	70	4	20	22	8.0	4.8
Balanced Growth Economies	150	24	285	15	122	51	5	25	10	5	3.3
Primary Exporters	308	30	224	18	48	47	0.2	3.7	4	19.7	2.7
Current Oil Exporters	668	40	940	10	70	55	1.3	40	5	20	3
Agricultural Exporters	340	23	440	12	77	57	3	6	3.5	8.2	2.5
Other Agricultural	174	14	81	21	75	42	3	8	2	6	2.5

Population weighted averages of country data

EXHIBIT 58. RELATIVE ENERGY-INTENSIVENESS OF MAJOR INDUSTRIAL SECTORS FOR SELECTED COUNTRIES

Sector	Portugal				Spain				Yugoslavia ⁴			
	Direct		Total		Direct		Total		Direct		Total	
	Actual ¹	Relative ²	Actual ³	Relative ²	Actual ¹	Relative ²	Actual ³	Relative ²	Actual ¹	Relative ²	Actual ³	Relative ²
1. Agriculture, forestry, hunting	0.0120	1.00	0.0276	1.00	0.0126	1.00	0.0433	1.00	0.0050	1.00	0.0242	1.00
2. Food, beverages, tobacco	0.0102	0.80	0.0305	1.30	0.0105	0.83	0.0570	1.32	0.0313	5.40	0.0743	3.07
3. Energy	0.0777	6.07	0.1003	3.92	0.3017	23.94	0.4447	10.27	0.2135	36.01	0.2926	12.09
4. Mining and quarrying, excluding coal, petroleum and natural gas extraction	0.0656	5.13	0.0763	2.76	0.0424	3.37	0.0702	1.62	0.0410	7.21	0.0910	3.76
5. Basic metals	0.0037	6.54	0.1457	5.20	0.0656	5.21	0.2240	5.17	0.0001	13.81	0.2320	9.59
6. Manufacture of transport equipment, machinery, instruments	0.0140	1.16	0.0627	2.27	0.0104	0.83	0.1004	2.32	0.0219	3.70	0.1105	4.57
7. Manufacture of chemicals; chemical, rubber and nonmetallic mineral products	0.0775	6.05	0.1273	4.61	0.0765	6.07	0.1699	3.92	0.0774	13.34	0.1630	6.74
8. Manufacture of wood and cork; furniture, paper and paper products, printing	0.0225	1.76	0.0520	1.00	0.0105	1.47	0.0615	1.42	0.0343	5.91	0.0000	3.64
9. Manufacturing of textiles, footwear, leather and leather goods	0.0102	1.42	0.0469	1.70	0.0007	0.69	0.0552	1.27	0.0160	2.90	0.0647	2.67
10. Construction	0.0165	1.29	0.0655	2.37	0.0122	0.97	0.0062	1.99	0.0116	2.00	0.0603	2.02
11. Trade, storage, warehousing, transport, communications, restaurants	0.0315	2.46	0.0430	1.56	0.0315	2.50	0.0506	1.35	0.0392	6.76	0.0630	2.64
12. Ownership of dwellings, banking, insurance, government and other services	0.0102	0.00	0.0469	1.70	0.0102	0.01	0.0200	0.40	0.0000	0.00	0.0000	0.00

¹ Ratio of the value of energy inputs of a sector to the value of output of that sector -- around 1965.

² Ratio of "Actual" value of sector to the "Actual" value of Sector No. 1.

³ Additional energy (in currency units) per currency unit of final demand -- around 1965.

⁴ Centrally-planned economy countries do not value services as a part of net national product.

Source: United Nations, Increased Energy Economy and Efficiency in the ECE Region. New York: 1976, pp. 14-15, 18-19.

ranges indicate the wide variation from one sector to another and, within a single sector, among countries with different factor proportions, product mixes, quality requirements, etc. They thus illustrate the potential energy consumption impacts of both changes in relative sectoral emphasis and technological or product changes within a given sector.

4.1.1 Industry

Virtually all LDCs have a broad spectrum of industrial activity ranging from traditional handicrafts such as weaving and pottery (much of which may not show up in a country's GDP accounts) to highly capital-intensive "modern" industrial complexes such as refineries, petrochemical plants, and iron and steel plants. The great majority of modern industry is concentrated in the industrialized and balanced growth LDCs, who account for the major share of all manufacturing output included in GNP statistics for the LDCs addressed in this report.

The structure of the industrial sector varies substantially among individual LDCs depending upon the local natural resource base, labor skills and costs, whether export stimulation or import substitution policies are being pursued, and so forth.

As a gross generalization, the modern industrial sector usually consists of the processing of primary minerals (for example, aluminum from bauxite or phosphoric acid from phosphorus), export industry (e.g. textiles or, in East Asia, electronics), production of intermediate goods (e.g. fertilizers or other chemicals or steel), agricultural processing for domestic consumption and export, and as countries develop, certain basic industrial sub-sectors supported by infrastructure investment (e.g. cement or other construction materials for building roads and housing, and the assembly of bicycles, buses, and other transport equipment). Only in the largest countries which have emphasized import substitution has substantial industry developed in support of direct consumption. Such industry typically starts with assembly operations (e.g., of refrigerators, automobiles, etc.) and progresses backwards to more basic production as domestic purchasing power and production skills warrant. Because of the concentration of income and wealth in a relatively small fraction of the population, even these countries have a domestic market for relatively expensive, capital-intensive goods which has limited backward integration except where export opportunities have existed.

The modern sector accounts for the far greatest proportion of commercial energy consumption in LDCs, because of both the substantially greater energy intensity of most such operations and their primary reliance on commercial energy. At the other extreme, local handicrafts production (primarily producing goods for the bulk of the population which has extremely low personal incomes) must produce goods with very low embodied input values. Thus, the "traditional" sector is generally small-scale (relying primarily on family, rather than purchased, labor), and whenever possible relies on either discarded scrap materials or extremely inexpensive raw materials (for example, locally available wood or aggregate). It also involves relatively low capital investment per work place and per unit of output, and economizes on its use of purchased energy (relying primarily on human or animal power and locally available noncommercial energy such as wood or charcoal).

The industrial sector, particularly the modern industrial sector, has traditionally been the focus of many if not most LDCs' development efforts, and it remains so. As discussed in Section 4.2, the relatively industrialized LDCs are better off in terms of annual income per capita, income distribution, and many other indicators of well-being. Because of their narrow domestic markets and their need for foreign exchange, many countries such as South Korea have tried to develop industrial export markets. LDC exports of manufactures to developed countries increased from \$12 to \$27 billion between 1972 and 1976 (which is still substantially less than 10% of all manufacture exports to developed countries), with most of the increase occurring in "textiles, clothing, steel, transportation equipment and certain mechanical and electrical engineering products."* Other countries such as India have industrialized as part of an "import substitution" strategy. The Declaration and Plan of Action passed by the UNIDO Second General Conference and endorsed by the UN General Assembly calls for expansion of the LDCs' share of world industrial production from 7% in 1975 to 25% by the year 2000.

Although the emphasis on industrialization remains, the criteria for evaluating strategies for it appear to be changing. In particular, there is a growing concern that capital-intensive industrialization strategies by capital-scarce LDCs both are ineffective and a tortuously slow way of improving the well-being of the bulk of their people. It is felt that the traditional emphasis on expensive "enclave" industries should be replaced by an industrialization strategy which more rapidly spreads the benefits of growth over a larger portion of the population. This concern is reflected in the "appropriate technology" emphasis on low capital investment per work place called for by the International Labor Office, the Tinbergen "RIO" group, the Overseas Development Council, and others for broad growth, employment, and income distribution strategies which would raise all the world's population to at least a universally acceptable level of well-being (that is, at least having a reasonable chance of surviving past infancy and of not starving thereafter) by the year 2000.

This strategy implies, both within the industrial sector and for the economy as a whole, an increasing emphasis on the allocation of scarce capital resources in order to maximize the direct and secondary impacts on the growth of productive employment in an LDC's populace. Secondly, it implies a greater emphasis on producing goods which satisfy the basic human needs of the country's population. To the extent that energy is also a scarce and expensive commodity, there will be an emphasis on the allocation of scarce energy resources (particularly oil) to the same ends.

Because in many countries much "traditional industrial" production is not picked up by GNP accounting, industrial production statistics probably are weighted in favor of "modern" production. Also, energy intensity statistics generally are available only for the developed countries and for the relatively highly industrialized LDCs; and in all cases only commercial energy and perhaps

* Oliver Long, Director-General, General Agreement on Tariffs and Trade (GATT).

fuelwood are included. Nevertheless, the available data on industrial structures for selected countries (Exhibit 58) generally indicate that even those countries which have successfully industrialized display widely differing patterns of development. This suggests that despite the general LDC desire to concentrate on such "critical" industries as iron and steel, there actually is a broad range of structural alternatives to achieve industrialization.

Within a given industrial sub-sector energy consumption can vary markedly between plants depending upon such factors as the age of the facility, its location, the mix of energy sources employed, and many other considerations. These variations usually can be traced to tradeoffs made at the time the particular plant was built, capital (investment), labor, energy, raw materials and availability, and to decisions regarding the scale of the plant to be constructed. Different countries have their own unique sets of costs and availability for these four factors; the development of specific industries in different countries will therefore vary, reflecting different tradeoffs among these factors. Inter-country variations in the development of specific industries is particularly accentuated when comparing LDCs with developed countries, because of broad differences in labor skills and costs, available infrastructure, capital availability, and other factors. While there are likely to be wide variations among countries, comparisons of developed country energy intensities with those of LDC industry subsectors suggest that industry's use of commercial energy is concentrated in a few energy-intensive subsectors. These are, predominantly, petroleum refining, petrochemicals, pulp and paper, ferrous and non-ferrous metals, and cement. We discuss below the range of energy conservation and/or fuel-switching possibilities for these sectors.

- Petroleum Refining

Petroleum refining is an energy intensive (and particularly petroleum intensive) process which consumes the equivalent of 3-12% of every barrel of crude processed to sustain its own operations, the actual amount depending on the complexity and conversion intensity of the refinery processing scheme. Exhibit 59 illustrates the current levels of energy consumption in refineries around the world:

The primary source variation is not relative energy efficiency, but rather relative refinery complexity. The simplest refineries (e.g., topping units) have the lowest energy consumption levels; while more complex refineries require more internal process energy. Exhibit 60 illustrates the complexities associated with several typical refinery configurations (using the replacement cost of all process units in a refinery divided by the replacement cost of a single atmospheric crude distillation unit of the same capacity as a measure of complexity).

EXHIBIT 59. SPECIFIC EFFICIENCIES FOR PETROLEUM PRODUCTS
(10⁴ kcal. Per Ton of Product)*

Ireland	42.5
Italy	44.8
Japan	46.0
Sweden	49.0
Denmark	53.0
Spain	60.0
United Kingdom	73.4
Germany	80.0
United States	89.7
New Zealand	131.2
Canada	179.6

* Source: OECD, Energy Conservation in the International Energy Agency, Paris: 1976.

EXHIBIT 60. REFINERY COMPLEXITY VERSUS CONFIGURATION*

<u>Configuration</u>	<u>Complexity</u>
Topping	1.20-1.21
Asphalt	2.02
Hydroskimming	2.50-3.54
Hydrodesulfurization	4.78-4.84
Catalytic cracking	5.05-6.20
Cat. cracking with coking	6.66-8.75
Hydrocracking	5.74

* Source: Gordian Associates, Small Refiner Bias Analysis, Department of Energy, December 1977, p. 65.

Refineries in developing countries are likely to have low complexity and hence low internal energy consumption relative to those in developed countries. Because refining technology is well known and relatively uniform worldwide, it is unlikely that newly constructed refineries will incorporate technology permitting energy consumption levels to drop substantially below those shown previously, particularly since recent technological developments have focused on the more complex units, e.g., new catalysts for use in naphtha reforming, catalytic cracking, and fuel oil desulfurization. Also, there is no known labor-intensive but capital- and energy-economizing "appropriate technology" substitute. Instead, refineries in LDCs must rely on improved operating procedures and basic engineering skills to improve conservation in refineries, e.g., increased waste heat recovery from process streams and furnace stack flue gas, use of computer control to optimize operations, recovery of hydrocarbons lost to flares and tank vents, and increased insulation. Opportunities for fuel switching (particularly to use coal) theoretically exist, but in practice are unlikely to be implemented in view of the convenience of using a single fuel for both feedstock and internal process energy requirements. As noted in Chapter 2, costs per unit of output increase rapidly as plant size declines. Also, a refinery probably is the best example of an "enclave industry" which neither employs substantial local labor nor draws supplies or services from the local economy. Thus, a refinery is generally a sound industrial development alternative, but only where supported by indigenous crude oil supplies and an adequate local regional market.

- Iron and Steel

Developing countries have substantially increased their share of world production and consumption of steel during the last five or six years. Many have tried to develop their steel industry in an effort to meet domestic market needs to export processed raw materials rather than ores. A number of LDCs with relatively large domestic markets such as Brazil and India are taking steps to raise their steel production and capacity; many less highly developed countries are trying to set up ore or soap processing plants to increase their foreign exchange earnings.

Because of the large amount of capital required to set up a large integrated steel mill, it is likely that the steel industry in LDCs will develop primarily through construction of "mini-mills" -- relatively small electric (arc or, recently, induction) furnaces operating on scrap or inexpensively produced "sponge iron," as opposed to integrated operations

producing steel from ore and including such operations as coke ovens, blast furnaces, etc. Energy consumption levels are significantly lower in mini-mills due to elimination of these energy intensive operations. On the other hand, some large iron ore exporters will choose integrated steel mills, despite their capital and energy intensity in order to compete more effectively in the international market.

Exhibit 61 illustrates current levels of energy consumption in the production of steel in various EEC/OECD countries. Since the theoretical maximum energy required to transform ore into steel is 209×10^4 kcal/ton, the lowest energy consumers shown (some of which have average energy efficiencies below this level) are largely mini-mill operations.

EXHIBIT 61. SPECIFIC EFFICIENCIES FOR CRUDE STEEL
(10^4 kcal. Per Ton of Product)

Ireland	139.7	(e)
Spain	180.0	(e)
Norway	189.0	(e)
Denmark	236.0	
Germany	326.0	
Italy	334.0	
Sweden	397.8	
Austria	450.0	
Netherlands	470.0	
United Kingdom	478.0	
Turkey	500.0	
Japan	513.3	
United States	543.0	
Canada	555.0	
Luxembourg	701.0	
New Zealand	738.9	

Source: OECD, Energy Conservation in the International Energy Agency, Paris: 1976, p. 17 and, for U.S., Gordian NATO/CCMS study.

Energy consumption in new LDC mini-mills is likely to be somewhat lower than the lowest values quoted above, since they reflect average energy usage of many plants built over a number of years, virtually all prior to 1973. Also,

a number of private companies are working to develop ways to substitute the direct firing of coal for the use of electricity in mini-mills. Alternative technologies such as simple grey iron foundries and the "backyard furnaces" characteristic of the Peoples' Republic of China's "Great Leap Forward," are unlikely to be of significance worldwide, although they may be useful in traditional economics as a small-scale, relatively low cost way of making low-precision/low-structural-strength products from locally available scrap or iron ore.

The role of an iron and steel plant in an LDC's development depends on each country's situation. Consumer products requiring the reduction even of scrap are so expensive that they are beyond the means of the bulk of an LDC's population, even using "appropriate" methods. Infrastructure investment in most countries is unlikely to provide a sufficient market -- for reinforcing bars, perhaps truck axles, etc. -- to justify a steel mill. Integrated steel mills using local iron ores to produce for export generally are expensive, must produce to international specifications (which generally are much more stringent than local LDC standards), must compete with very aggressive developed country steel industries, and may be denied access to the most promising developed country markets. Steel mills also have limited primary and secondary employment impacts per dollar of capital investment. On the other hand, some LDCs have successfully developed export markets for steel, particularly scrap-devised steel products, thus creating a valuable source of foreign exchange. Also, once they have developed mini-mills, some countries such as India have successfully integrated backwards into relatively inexpensive sponge iron production or have "moved up" to integrated mills.

- Aluminum

The production of aluminum requires three distinct operations: bauxite mining, bauxite refining to aluminum (Bayer process), and aluminum smelting to aluminum (Hall process). Most bauxite mining operations in tropical underdeveloped countries are large scale and are highly mechanized in order to achieve an economic operation in a remote location where all support facilities (e.g., utilities, transportation, etc.) have to be provided by the mining operation. In locations where the supporting infrastructure is already in place, where there is little overburden, where the ore is of high grade, or where integration with aluminum production near the mine site is possible (as in Brazil and India), mining can be carried out on a smaller scale. Operations in aluminum plants also are capital and energy intensive and are sensitive to scale particularly regarding energy and labor requirements.

In aluminum reduction the major input is electric power for separating the metal from its oxide. Unit labor requirements

decline as plant capacity increases, although the extent of this is limited because a large part of the labor force is engaged in operations that require repetitive service at the unit level, such as stirring alumina in cryolite and furnace reconstruction. There is some capital-labor tradeoff, however; in Canada, for example, labor requirements are reportedly 26 man-hours per ton, compared to 120 man-hours per ton in Ghana.*

Current representative energy requirements for the production of aluminum are presented in Exhibit 62 for selected EEC/OECD countries:

EXHIBIT 62. SPECIFIC EFFICIENCIES FOR ALUMINUM
(10⁴ kcal. Per Ton of Product)

United States	946.5*
Netherlands	1,290.0
Austria	1,346.0
Japan	1,385.0
Germany	1,503.0
Norway	1,591.0
Sweden	1,648.2
United Kingdom	2,106.6
New Zealand	2,164.5
Spain	2,800

* Excluding bauxite mining.

Source: OECD, Energy Conservation in the International Energy Agency, Paris: 1976, p. 18.

Reported energy consumption for aluminum production of 25,000 kWh/ton in India,** which equates to about 2370 x 10⁴ kcal/ton, illustrates that even in LDCs, aluminum production is characterized by high power consumption. This is due to the fact that energy conservation measures in this industry are capital-intensive and generally consist

* United Nations Dept. of Economic and Social Affairs, Pre-Investment Data for the Aluminum Industry. New York: 1966, p. 13.

** United Nations Dept. of Economic and Social Affairs, Pre-Investment Data for the Aluminum Industry. New York: 1966, p. 15.

of modification to existing equipment. New R&D may reduce energy consumption in aluminum smelting perhaps as much as 20-25% below the levels characteristic of the Hall process, but R&D is highly unlikely to so change the process of creating aluminum as to make smelting, which is inherently energy-intensive, unnecessary. Since the major production process is electrolytic, it is virtually certain that the major energy input to the process will continue to be electricity, with only minor inputs of fuels for ancillary uses. Therefore, to the extent that hydropower remains available in specific LDCs, these countries are likely to develop or expand their aluminum production operations. Indeed, a migration of aluminum processing plants to hydropower-rich areas near bauxite sources is expected. At the same time, LDCs without available hydropower facilities are unlikely to develop an aluminum production capability.

- Cement

Energy consumption in cement production is a complex function of numerous production-related variables -- including technology employed, raw materials used, age and capacity of kilns, and many other factors -- and such market-related factors as the quality requirements (for example, the load-bearing characteristics) of the final product. The variation in energy consumption per ton of product as produced within EEC/OECD countries is illustrated in Exhibit 63.

EXHIBIT 63. SPECIFIC EFFICIENCIES FOR CEMENT
(10⁴ kcal. Per Ton of Product)

Austria	90.0 - (d)	Spain	130.0
Germany	90.8	Netherlands	131.4
Canada	95.0 - (d)	United Kingdom	138.4
	148.0 - (w)	Sweden	139.7
Italy	96.0	Ireland	153.4
Turkey	98.0 - (d)	United States	161.4
	139.0 - (w)	Denmark	164.0
Norway	115.2	New Zealand	174.8
Japan	119.6		

(w) Wet Process
(d) Dry Process

Source: OECD, Energy Conservation in the International Energy Agency, Paris: 1976, p. 18, based on a study for the IEA by Gordian Associates Inc., and Gordian NATO/CCMS studies.

One point illustrated in Exhibit 63 is that wet-process kilns generally require significantly more energy input per ton of cement produced. The age of plants is also an important factor. The German cement industry, for example, consists essentially of modern plants and hence exhibits low overall energy consumption. In contrast, over 20% of the kilns in the U.S. were built before 1934, resulting in a low overall energy efficiency.

Newly constructed cement plants in LDCs and developed countries will undoubtedly take advantage of the many improvements in production technology which permit reductions in plant energy consumption per unit of output. These include the use of waste heat boilers, blended cements, preheaters, precalciners, and roller mills. A recent NATO/CCMS report which examines these and other technologies cites the most efficient plant in Europe as consuming a total (including fuel and electricity) of about 80×10^4 kcal/ton. Incorporation of the most modern technology in plants constructed in LDCs would result in energy consumption levels comparable to that figure. Two factors will influence this level, however. On the one hand, many of the emerging energy technologies are capital-intensive and may not be suitable for LDC adoption. On the other hand, the likelihood of substantially less demanding product specifications in LDCs should enable energy consumption levels to be even below that of the most efficient European plant.

The major energy user in the cement plant is the kiln, which has a great deal of flexibility in terms of fuels which can be used. For example, since 1950 the U.S. kiln fuel distribution shifted from 61% coal, 10% oil, and 20% gas to 42% coal, 12% oil, and 46% gas. It now is converting back rapidly to coal. Solid wastes also have been used successfully as a fuel. Thus, in addition to being able to reduce overall energy consumption levels, LDCs have substantial opportunity to adapt to various fuels' availability and cost. Clearly, cement manufacturers will use the most economic fuel available.

Finally, virtually all countries face a choice among building materials, and there may be less expensive and less energy-intensive materials in many LDCs. The predominant example is in non-high rise construction where adobe, wood, brick, etc. may be more appropriate to local needs. However, in building roads to international standards cement may be preferable to asphalt surfaces.

4.1.2 Transportation

Since the end of 1973 many LDCs have seen the health of their economy deteriorate and their public and private transport services disrupted by

the economic instability and price escalation incurred for such services. Remote rural areas of Asia, Africa, and Latin America have retrogressed due to the high cost of commodity transport to and from such areas. Transport has been hurt both by the reluctance by some nations' government authorities to permit needed common carrier increases in goods tariffs and, conversely, other nations' permitting the escalation of transport price and not only incurring reduced demand for transport, but also (due to increases in delivered costs) for indigenous commodities.

Within subsistence cultures the portion of GDP required for all transport and communication services is modest, generally under 29%. In developing economies the capital investment and operating expenses required for reliable transport rights of way and for the development of vehicle fleets can range from 5-20% of GDP. This percentage parallels or in some cases exceeds the transport share of GDP in developed countries.

In LDCs, transportation capacity is almost universally inadequate to meet these countries' needs for the movement of goods and people. For example, India's transport sector is quite highly developed by LDC standards, but broad areas of the country are still inaccessible by rail (its predominant form of transport) or by conventional road vehicles. South of the Sahara, African nations have only one mechanized vehicle per 30-200 inhabitants; most of these are public or commercial vehicles (in fact, worldwide, public service trucks and buses comprise 30-50% of all vehicles in an LDC's fleet).

The transport sector is unquestionably the most difficult LDC sector in which to find opportunities for energy conservation or petroleum substitution. Most LDCs other than India have found highway transport to be responsive to their needs and rapidly available relative to other surface transport. Hence, over the last two decades they have increased their dependence on this mode. Prior to 1973 most LDCs were experiencing 10-20% annual increases in domestic petroleum sales.

Within urban areas of medium to high residential density and concentration of work locations, non-petroleum options for passenger transport (e.g. electrified rail) may at times be feasible. However, a multitude of other factors, including the need to accommodate shifts in activity centers, social requirements for the maximization of employment, and high capital costs of conversion to rail, suggest that this option will have only limited appeal. Bicycles and walking already are relied upon extensively in most LDC cities and can be expected to be given up rapidly as personal incomes increase. A few high income developing countries (notably in Latin America and the Mediterranean) may have limited potential to restrict private passenger cars, as South Korea and a few other countries are doing. However, the potential energy savings relative to those in developed countries are infinitesimal. Exhibits 64-66 portray the ranges of energy use for various present modes of mechanized transport.

In most LDCs transport outside the cities does not afford energy conservation opportunities and in fact may be an area of rapid growth in energy, and particularly petroleum, requirements. Despite the urbanization trend in

EXHIBIT 64. ENERGY REQUIREMENTS OF PASSENGER TRANSPORTATION MODES

	Assumed Passenger Loading	Vehicle Miles Per Gallon of Fuel or Equivalent	Passenger Miles Per Gallon of Fuel or Equivalent
Heavy Rail Transit (Subway) Car Peak Load	135	4.00	540
Intercity Passenger Train	540-720	0.50	270-360
Transit Bus Peak Load	75	4.10	307
Intercity Bus	47	6.00	282
Commuter Rail Car, Diesel Powered	125	2.00	250
Heavy Rail Transit (Subway) Car Off-Peak Load	35	4.00	140
Transit Bus, Off-Peak Load	30	4.10	123
Rail Turbine Train	320	0.33	110
Standard Size Automobile Intercity, Maximum Load	6	18.00	108
Standard Size Automobile Urban, Maximum Load	6	14.40	86
Wide-Body Commercial Jet Aircraft, 1,000 Mile Flight	256-385	0.14-0.22	54-60
Twin Jet Commercial Aircraft, 500 Mile Flight	68-106	0.44-0.54	37-47
Average Commuter Automobile	1.4	13.5	19

Source: American Public Transport Association, Transit Fact Book '75-'76 Edition, Washington, D.C., 1976, page 41.

EXHIBIT 65. ENERGY INTENSIVENESS FOR TRUCKS - 1974-1980

Vehicle Type	Cargo density lbs/ft ³	Maximum payload in tons	Trip Length (statute miles)	Average trip time hrs @ MPH	Type of fuel	Vehicle statute miles/ gallon	Specific energy stop/start cycle	
							Ton-miles per gallon	BTUs per mile
Urban, truck	20-100	8		.4/25	Gas	8	64	1,953
Urban, truck	20-100	8		.4/25	Diesel	12	96	1,446
Urban, Truck	10-30	3.1	10	.4/25	Gas	8	25	5,040
Intercity, truck	20-100	25	100	1.8/55	Diesel	5	125	1,110
Intercity, truck	15	14.3	100	1.8/55	Diesel	4.8	69	2,023

Source: U.S. Department of Transportation, Energy Statistics, Washington, D.C.: U.S. Government Printing Office, 1975, page 139.

EXHIBIT 66. ENERGY INTENSIVENESS FOR FREIGHT TRAINS, 1974-1980

Vehicle Type	Cargo density lbs/ft ³	Maximum payload in tons	Trip Length (statute miles)	Average trip time hrs @ MPH	Type of fuel	Vehicle statute miles/ gallon	Specific energy stop/start cycle	
							Ton-miles per gallon	BTUs per mile
Intercity, train								
Config. I:	25	1000	100	2.26 @ 44	Diesel	0.14	273	550
Config. II:	25	700	100	2.86 @ 35	Diesel	0.17	420	330

Source: U.S. Department of Transportation, Energy Statistics, Washington, D.C., U.S. Government Printing Office, 1975, page 140.

LDCs, by the year 2000 only Latin America will see the majority of its population residing in urban areas. In LDC rural areas there will be more people in the year 2000 than existed totally in the world in 1950. When combined with national economic growth this population increase will accelerate transport energy demands in the post-1980 period.

If social welfare considerations would permit and agricultural resources were available, millions of rural LDC citizens could live a self-sufficient life requiring minimal external assistance. However, within most national and ethnic groups there is little or no desire for such a limited lifestyle. Even assuming a heavy emphasis on food self-sufficiency and appropriate technology, virtually all LDCs will require greater transport activity and capacity for their well-being. Rural areas which now have rail or all-weather paved highway capacity require much less energy for the operation and maintenance of vehicles and rights of way than locations which need totally new roads and the concomitant development of vehicle fleets. The latter will constitute an area of high marginal cost and high marginal energy intensity. The manufacture of vehicles for all transport modes can be accomplished without major reliance on petroleum products. However, the development of transport tracks or roadways to international engineering standards can be accomplished only with major energy outlays, largely petroleum. Some portions of this construction can be labor-intensive, but the use of heavy earth moving equipment and the manufacture of asphaltic surfaces will be totally dependent on petroleum derived fuels and lubricants. While cement and steel track production is energy-intensive, it offers opportunities for the substitution of other fuels, notably coal.

New propulsion systems may or may not represent viable energy substitutes for petroleum. Battery powered, long distance, heavy duty vehicles have not yet proven to be economically feasible for large scale application; if it indeed becomes feasible, it appears to be at least 15 years into the future. Other methods of electric propulsion require fixed guideways or fixed distribution lines. Other than for railway operation, such fixed overhead or third rail propulsion systems with central plant generation have not been developed for intercity or even regional rural uses. Various nations, including Japan, Germany, USSR, USA and Brazil, have been experimenting with vegetation-derived alcohol fuel sources. Although these liquid fuels are technically successful, the widespread development of a supporting industry is not yet attractive in either centrally-planned or western economies. Brazil is at the forefront of experimentation for this fuel option, being in the process of adding methanol plants alongside its numerous sugar refineries. While officials there still generally regard the enterprise as speculative, they hope that methanol eventually will furnish 20-25% of Brazil's total domestic transport fuel consumption. Particularly within West Africa where substantial vegetable matter could be available, methanol production may have promise if it does not endanger the production of basic food grains.

Similarly, non-mechanical means of transport will not provide the high-tonnage, long distance capacity required for economic progress in areas larger

than neighborhoods. Non-motorized vehicles can provide a preliminary collection function within the network of transport requirements and can satisfy local demands for the movement of daily goods up to 75-100 tons over a distance of less than 10 kilometers. While much intra-zonal movement within urban and village settings can be accomplished with bicycles, animal-drawn vehicles, and other non-mechanical or low-power vehicles, these are similarly limited by the effective transport radius and carrying capacity.

In short, there are limited options in the LDC transport sector for responding to the rise in oil prices. Although the industrialized nations could conserve sizable amounts of petroleum fuels by converting to more energy-efficient transport and transport organization methods, the LDCs do not have large amounts of inefficient or unnecessary private transport within rural and urban areas.

In most LDCs rural areas will be affected more seriously than urban areas within the first stage of energy limitations for transport. Accessibility to these areas will be reduced, and, although the economically important foodstuffs and export-oriented agricultural products will still be able to be transported, it will be at higher costs. Other types of transport activities will be constrained or foregone. In a more severe secondary stage, if major transport capacities are reduced or abandoned within national and regional settings, the urbanized areas' supplies of foodstuffs and other materials, including wood, may be gravely affected. Equally important, restriction in transport will result in a greater concentration of industrialized ventures in limited urban areas within the LDC rather than greater dispersal of economic and industrial projects. This concentration, which already has been identified by the World Bank and other international institutions as a national impediment in several LDCs, will be exacerbated by the impact of the energy situation on LDC transport.

4.1.3 The Urban Residential Sector

LDC urban agglomerations are growing at two to three times the rate of their overall population growth (Exhibit 67). In general, this has given rise to two distinct patterns of residential development: the urban "informal" sector, and the urban "formal" sector. Although the characteristics of the two sectors vary considerably, both are associated with higher energy consumption than agriculture.

The formal sector is usually comprised of civil servants, professionals, merchants, and industrialists. In some LDCs the urban working class is part of the modern sector in terms of energy use patterns; in other countries, it falls either in the informal sector or on the borderline. The informal sector is comprised of the suppliers of "petty services," the unemployed, seasonal workers, and other urban poor.

EXHIBIT 67. GROWTH IN TOTAL URBAN AND PRINCIPAL CITY POPULATION
1960-1970 IN DEVELOPING COUNTRIES

Country	Total Population 1970 (thousand)	Annual Growth Rate 1960-70 (%)	Urban Population 1970 (thousand)	Annual Growth Rate 1960-70 (%)	% Urban 1960 1970		Principal City	Population (thousand)	Annual Growth Rate 1960-70 (%)	Principal City Population as % of Urban Population
A. Eastern Africa										
Botswana	628	3.0	140	3.3	20	22	Gaborone	16	—	—
Barotsi	1544	2.0	53	7.2	2	3	Barotsi	—	—	—
East African Community	22833	3.0	2661	7.5	6	8				
Kenya	10251	3.0	1000	5.1	8	9	Nairobi	50	6.0	50
Tanzania	12252	3.4	1045	6.6	5	7	Dar es Salaam	150	9.0	9.0
Uganda	8542	2.5	612	4.2	4	7	Kampala	—	—	—
Ethiopia	24754	1.5	1643	2.4	6	7	Addis Ababa	63	3.5	3.5
Lesotho	946	2.5	16	7.5	1.5	2	Maseru	—	—	—
Malawi	6854	2.4	891	4.3	11	13	Tanzania	62	3.5	4.5
Mali	443	2.5	240	10.1	3	5	Blantyre	174	—	7.3
Mauritania	157	2.7	469	5.1	42	18	Port Louis	146	—	31
Rwanda	3674	3.2	10	8.3	2	3	Kigali	—	—	—
Somalia	2841	3.5	713	6.0	23	24	Mogadishu	130	—	34
Sudan	15331	2.5	1233	4.3	7	8	Khartoum	42	3.4	34
Swaziland	419	4.5	18	9.4	3	4	Mbabane	—	—	—
Zaire	1743	2.1	3000	3.5	15	17	Kinshasa	110	10.0	15
Zambia	435	3.1	117	6.4	19	25	Lusaka	110	—	11
B. Western Africa										
Cameroon	5228	2.5	748	6.5	8	13	Douala	123	4.0	31
Central African R.	1585	2.5	1237	6.4	14	24	Bangui	130	—	15
Chad	3562	1.5	125	7.5	4	8	Fort Lamy	—	—	—
Congo Rep. R.	295	1.5	345	1.4	25	28	Brazzaville	150	4.0	—
Dahomey	2732	2.5	428	6.0	12	16	Cotonou	175	—	—
Gabon	485	1.0	101	6.5	12	21	Libreville	—	—	—
Gambia	154	2.5	37	3.8	9	10	Bathurst	—	—	—
Ghana	8338	2.5	2890	6.5	23	34	Accra	752	6.0	24
Guinea	421	2.7	451	6.5	1	11	Conakry	123	7.0	5
Ivory Coast	4239	2.5	1244	9.3	16	28	Abidjan	180	11.0	—
Liberia	1161	1.7	344	10.4	13	30	Monrovia	—	—	—
Mali	5010	2.0	439	5.7	4	9	Bamako	124	5.5	—
Mauritania	1161	1.5	18	2.4	2	2	Nouakchott	—	—	—
Niger	2845	3.0	118	2.4	3	3	Niamey	—	—	—
Nigeria	66000	2.5	12825	6.0	17	21	Lagos	88	—	—
Senegal	2854	2.5	1031	4.0	24	27	Dakar	88	10.0	5
Sierra Leone	2850	1.4	880	3.8	11	14	Freetown	173	—	16
Togo	1851	2.5	185	4.2	10	17	Lome	—	—	—
Upper Volta	533	2.0	15	5.1	4	5	Ouagadougou	—	—	—
C. East Asia and Pacific										
British Solomon Islands	153	2.1	6	4.7	3	4	—	—	—	—
China (Taiwan)	1442	3.0	927	4.1	19	24	Taipei	2150	4.7	21
Fiji	340	3.2	106	3.8	18	23	—	—	—	—
Indonesia	118154	2.3	21136	4.2	15	18	Djakarta	458	4.7	21
Korea R.	8050	2.3	278	4.8	15	13	Pyeongtaek	700	7.5	—
Korea, South	12188	2.5	1247	4.1	28	28	Seoul	466	8.0	15
Malaysia	9376	3.1	421	5.3	28	48	Kuala Lumpur	630	4.0	15
Philippines	2248	1.2	28	7.3	7	12	—	—	—	—
Thailand	2225	2.5	887	4.3	22	23	Bangkok	4100	4.3	46
Singapore	2113	2.5	2113	2.5	100	100	Singapore	2113	2.5	100
Taiwan	11423	3.0	638	6.5	11	13	Bangkok	2100	6.0	4
D. South Asia										
Albania	18713	1.5	1138	2.3	6	7	Kabul	150	3.5	4
Ceylon	12585	2.5	2150	3.8	15	17	Columbo	1213	2.5	80
India	544621	2.4	10143	2.8	18	19	Calcutta	5113	1.5	5
Iran	28008	3.0	11306	4.8	33	38	Tehran	1250	8	12
Nepal	11143	2.5	187	6.0	3	5	Kathmandu	145	7.5	15
Pakistan	114231	2.1	1573	4.3	13	15	Karachi	1148	1.5	12
E. Europe, Middle East and North Africa										
Cyprus	631	3	11	3.5	15	48	Nicosia	112	—	13
Egypt, Arab R.	10111	2.4	1454	4.0	14	44	Cairo	5600	4.1	13
Israel	4761	2.7	123	2.7	18	61	Jerusalem	77	3.2	13

The population shift to the modern urban sector implies increases in income and changes in lifestyle. While both significantly increase energy consumption, the effect of the latter is greater. Adoption of a middle class status increases the energy intensity of consumption by providing ways of consuming energy that are unattainable to the majority of the population: electricity, refrigeration, personal motorized transport, televisions, radios, and so on.

Not only does the energy intensity of consumption increase for the higher income groups, but dependence on commercial energy increases as well. Estimates for various African nations show that a very large share of commercial energy consumption can be attributed to household consumption by urban middle and upper classes. The Ivory Coast's modern Hotel Ivoire is the fourth largest electricity consumer in the country, consuming nearly 2% of the national total.* The metropolitan area of Bangkok uses 75% of Thailand's total electricity consumption.** These consumption patterns often reflect long standing personal preferences, the satisfaction of which is a major motivating force. For example, heavy cement housing predominates even in climates where lighter, less energy-intensive construction materials would suffice. Consumption is also strongly influenced by the technological choices made by industrial nations.

Residential energy consumption in the urban informal sector reflects elements of both rural and urban patterns. The specific mix is highly variable, depending upon the city being examined. Electricity is not commonly available to residents of marginally urban areas, and cooking and heating often rely on traditional fuels. However, in several Latin American countries, for example, bottled gas has become a major cooking fuel. Similarly, while most homes in the informal sector are not electrified, cinemas, small shops and streets in the same areas often have electricity. Radios or small appliances powered by batteries or kerosene are also not infrequent in poor urban areas. Finally, residents of both the formal and informal urban sectors indirectly consume a great deal of energy through urban services: mass transit, street lights, sewer systems, pumped water, and other urban infrastructures.

In terms of reducing urban energy consumption, two major choices exist: the reduction of urban populations, or of their relative rates of growth; or the reduction of urban energy consumption. The latter can, in turn, take several forms:

- . The consumption of energy intensive products, including those which are energy intensive in production or in use (such as electrical gadgets and automobiles) can be limited. A wide range of economic policy instruments exists to achieve this result, but a specific discussion depends upon variables that are outside the scope of this report.

* UN Centre for Natural Resources, Energy and Transport.

** Overseas Development Council.

- . Interproduct substitution, replacing energy intensive goods with more energy efficient goods, can be used to provide substantially the same services: bicycles and motorcycles rather than automobiles, mass transit rather than personal transport, energy efficient appliances, lighter building materials, etc. In some instances, this process will involve simple substitution between existing goods. In other cases new methods such as the use of lightweight local construction materials in urban buildings and homes may have to be developed and popularized.
- . Renewable energy sources such as solar water heaters and solar home heating and cooling can be developed. As in rural areas, small scale technology using renewable energy sources can both reduce present consumption and provide an efficient means of increasing the energy inputs available to the urban poor. The specific technologies required for urban use are, however, somewhat more sophisticated and at a less advanced stage of development (e.g., photovoltaic solar cells).

Achieving energy conservation in the cities is made easier by high population densities, developed infrastructures, and the consequent ease of communication. Moreover, tax, price and similar incentives can be more effectively applied to affluent urbanites. However, the cumulative investment in the existing infrastructure and equipment is much greater in cities than in rural areas; this tends to limit the rate at which conversion can occur, except at very high energy prices.

4.1.4 Rural and Agricultural Sector

The majority of the LDC populations still lives in rural areas and is primarily engaged in agriculture. Agriculture's contribution to GNP varies from approximately 90% in the poorest nations such as Bangladesh, Rwanda, and Chad, to less than 20% in the most prosperous industrialized LDCs. Energy requirements for rural areas fall in three principal areas: increasing energy inputs, converting potentially available energy into usable forms, and increasing the efficiency of energy use.

Agricultural development is the key determinant of the growth prospects of the poorest LDCs. In the more advanced economies mining, industry or services are typically the leading growth sectors. Nevertheless, even the most prosperous developing countries require improved agricultural productivity to support their development -- first, to supply the burgeoning urban centers, and second, to improve living standards for the large share of their populations still living in the countryside.

Rural living tends to contrast sharply with the modernized lifestyles of the cities. It is generally characterized by subsistence production, limited trade, limited transport and communications, conservative social and economic patterns, and a relatively low level of technological sophistication. There are, course, numerous exceptions to any given characteristic, but the set seems broadly applicable.

Rural energy use is lower (per capita), and less diversified than urban energy use. Most rural energy is noncommercial, and the ratio of noncommercial to commercial fuel often exceeds 8 to 1. Sixty percent of these noncommercial fuels are used for cooking and space heating in village communities. The principal traditional energy forms utilized are wood, animal dung, crop residues, and human and animal power. Exhibit 68 shows the breakdown of commercial and noncommercial fuel use in an Indian village, and further sub-divides non-commercial energy by source.

Human labor and animal power are the principal forms of energy applied to traditional agriculture. The amount varies widely among and within countries. In many parts of rural Africa, for example, unassisted human labor is the only energy input. In Asia animals are widely used for plowing, while in certain LDCs (such as Taiwan and Korea) mechanization in agriculture is no longer uncommon. The application of energy through irrigation systems and fertilizer use is similarly uneven across LDC groups.

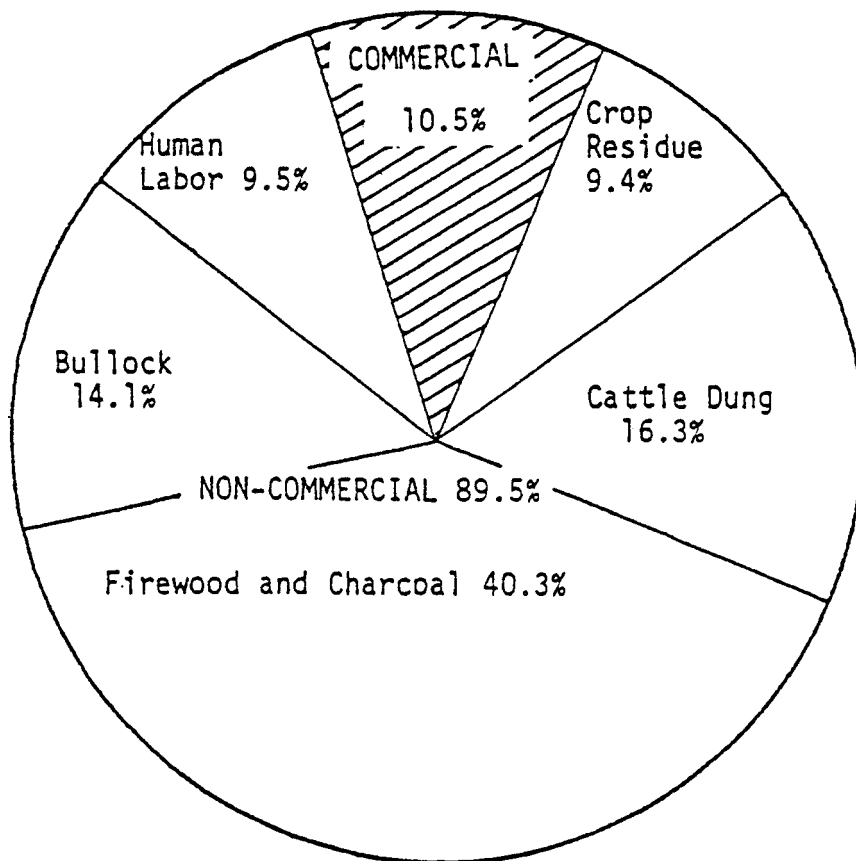
The predominant fuel types for cooking and space heating are wood, animal dung, and crop residues, with wood being by far the most important. This has resulted in the widespread depletion of forest reserves (see Section 2.2 and 4.2) and the need to devote increasing amounts of time to wood gathering. In a Nepalese village surveyed for the Overseas Development Council, wood gathering consumes two hours per day per family. In Niger, Mali, portions of Upper Volta, and other Sahelian nations, the nearest wood sources are often several hours away; this distance is increasing as pressure on the environment intensifies.

Crop residues are the most under-utilized of the three energy forms. To some extent, this results from its competing use for soil enrichment, and to some extent, there is a problem of converting these residues to a more readily usable energy form. Several promising technologies through which this problem might be overcome are discussed in Section 4.2.

Cross-country surveys of agricultural productivity suggest a positive correlation between energy inputs and outputs per acre. The specific input shortages that inhibit rural productivity are shortages of fertilizers, mechanical power for irrigation, and in many instances, of human and animal labor during cultivation. This latter problem often arises despite widespread under-employment in the countryside, and is attributable to a labor shortage during the peak season, followed by prolonged under-employment. In most of Africa only 10-15% of the arable land is under cultivation, largely for this reason.

In addition to being subject to peak season shortages, a great deal of the animal power used in agriculture is inefficiently applied. Thus, while the industrialized nations employ far more energy per acre, their energy output per unit of output is lower than for traditional agriculture (Exhibits 69 and 70). This partially results from the inherent efficiency of modern technology. However, cross-country comparisons show that labor intensive production is also consistent with high yields per acre, especially if combined with irrigation systems (Exhibit 71).

EXHIBIT 68. RURAL ENERGY CONSUMPTION IN INDIA, PERCENTAGE SHARES BY ENERGY SOURCE



Source: Overseas Development Council.

EXHIBIT 69. RELATIVE PRODUCTIVITY OF RICE GROWING IN SELECTED COUNTRIES
(Rice Yield in Kilograms per Hectare)

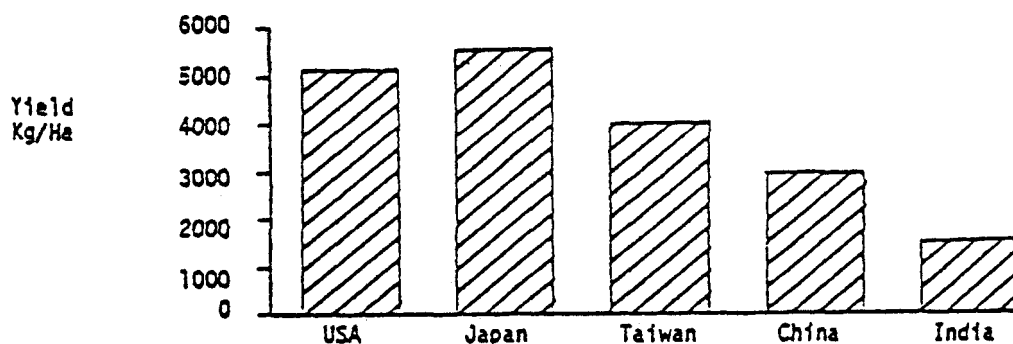


EXHIBIT 70. RELATIVE ENERGY INTENSITIES OF RICE PRODUCTION IN SELECTED COUNTRIES
(Million BTU Per ton of Rice)

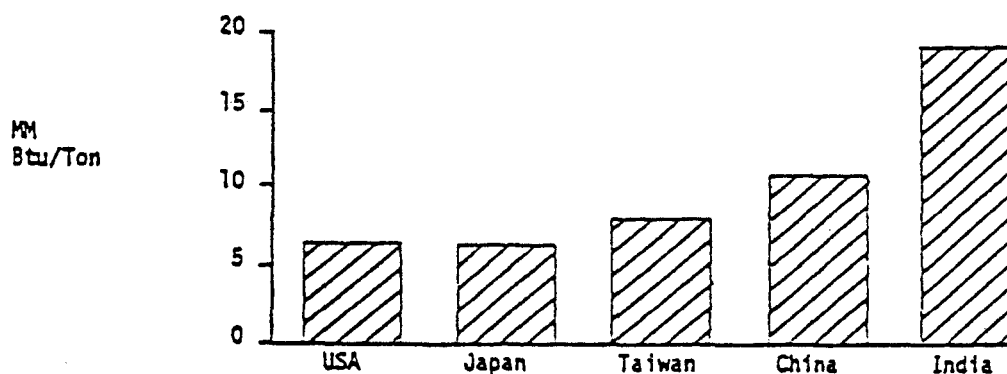
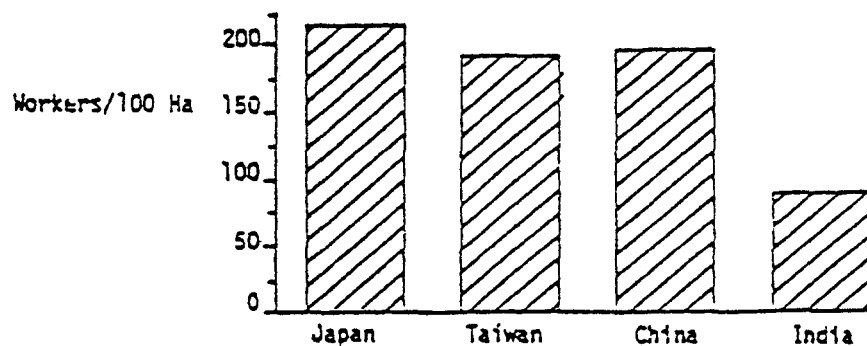


EXHIBIT 71. RELATIVE LABOR INTENSITIES OF RICE PRODUCTION IN SELECTED COUNTRIES
(Number of Workers per 100 Hectares)



The energy used in rural cooking and heating is also inefficiently applied. A large portion is lost in conversion, resulting in extremely low ratios of energy consumption to useful energy inputs. Several possibilities for improvement exist, some requiring changes in existing practices. For example, wood is often burned immediately after it is felled, while it still retains moisture from the living tree. Exhibit 72 shows that the energy efficiency of wood burning can be increased substantially by allowing it to dry (optimally for over a month). Other improvements depend upon the implantation of new conversion technologies. For example, biogasification permits the highly efficient use of natural wastes to produce gas and liquid fuels, while also enhancing the fertilizer value of the wastes themselves.

EXHIBIT 72. COMPARISON BETWEEN THE PERCENTAGE OF MOISTURE CONTENT AND CALORIFIC VALUE OF WOOD, DETERMINED ON DRY WEIGHT AND WET WEIGHT BASES

Percentage Moisture		Calorific Value (kilocalories per gram)	
Dry	Wet	Dry	Wet
0.0	0.0	5.0	5.0
10.0	9.1	4.5	4.5
25.0	20.0	4.0	4.2
50.0	33.3	3.3	4.0
100.0	50.0	2.5	3.3
200.0	66.7	1.7	3.0

Source: D.E. Earl, *Forest Energy and Economic Development*. London: Oxford University Press, 1975, Table 3.4, p. 24.

Two major areas in which energy can improve the quality of rural life are transportation and electrification, while major cutbacks in either area could seriously inhibit a country's development. Potential ramifications may arise in areas such as education, national integration, and the transfer of ideas and technology.

Transport plays a particularly important role in rural areas. A recent report on Mexico found evidence that paid transportation is as important a part of a rural family's expenditure as it is for urban families with the same income. Isolation from population and market centers increases the need for transportation as a communications, supply and marketing link. In some instances, modern transport systems are crucial to seasonal and other massive labor migrations. Such out-migrations frequently serve as a necessary prop to rural economies -- they can be expected to increase and to generate

a correspondingly higher modern transport demand. A recent analysis of labor immigration from Pakistan, Korea and Taiwan to the Middle East refers to it as "the first historic migration to have taken place by air." As indicated in Section 4.2, transportation is, unfortunately, an area in which very little prospect for energy conservation exists.

The outlook in rural electrification is somewhat brighter. It has been given high priority by many LDC governments, as evidenced by the growth in the number of electrified villages in India (Exhibit 73). For over 25 years, rural electrification was the only form of energy development in which the World Bank participated, and the Bank currently has substantial commitments for such projects worldwide. The rationale for this emphasis has been that rural electrification is part of the basic social infrastructure necessary for further development. While the energy crisis since 1973 has seriously set back rural electrification programs, the concept remains alive and viable. However, a shift in emphasis from centralized to decentralized systems is currently taking place. The latter would rely upon noncommercial, non-fossil and renewable sources such as solar, small scale hydropower and natural wastes; it thereby provides the prospect of combining rural electrification with a reduction in energy dependence. While offering a partial solution, small-scale technologies cannot respond to all potential rural needs, particularly in regard to rural industry of larger than handicraft proportions.

EXHIBIT 73. NUMBER OF VILLAGES ELECTRIFIED AND IRRIGATION PUMPSETS/TUBEWELLS ENERGIZED*

	Number of Villages Electrified	Proportion of Total Villages (%)	Irrigation Pumpsets/Tubewells Energized (thousands)
1950/51	3,100	0.5	21
1955/56	7,300	1.3	56
1960/61	21,700	3.8	198
1965/66	45,100	8.0	509
1968/69	73,700	13.0	1,081
1970/71	104,900	18.7	1,619
1971/72	122,100	21.6	1,890
1972/73	139,200	24.5	2,168
1973/74	156,000	27.5	2,440

* Numbers are for the preceding and first three months of the second year; e.g., the figure for 1950/51 is for March 31, 1951. The figures in the first column are rounded to the nearest hundred; the number of irrigation pumpsets and tubewells energized is given to the nearest thousand.

Source: CWPC, Electricity Supply Industry, Salient Data, February 1974, with figures for 1973/74 supplied directly by CWPC.

4.2 DEVELOPMENT OF RENEWABLE RESOURCES

LDCs require energy that can be produced at a low cost with a minimum of capital investment. Rural areas in particular would benefit from the increased availability of renewable energy, which would in turn raise living standards and increase agricultural productivity. This section discusses those new and revived technologies with a promising future for producing energy in LDCs.

4.2.1 Fuelwood

Great importance should be attached to the future supply of fuelwood (or some alternative fuel) in LDCs. In many areas the demand for this fuel has already outstripped supply. If sound forestry techniques are not used in meeting this demand, deforestation will occur. There are two serious consequences of this:

- . The productivity of the land will decrease due to soil erosion, increasingly severe flooding, creeping deserts, and declining soil fertility.
- . As firewood becomes increasingly hard to find and/or becomes too expensive for a large proportion of the population, substitute fuels will be sought. The most likely candidates will be animal dung, crop residues, and even lead litter, the burning of which will rob the soil of needed nutrients and organic matter, further undermining agricultural productivity.

For any LDC, the best approach to relieving the fuelwood supply problem will depend on the following: the availability of capital, the availability (or cost) of land, the nature of existing forests, the distance of sites from population centers, and social considerations. The last of these factors is extremely important: in order to manage forest resources effectively, one must have the cooperation and support of the populace. Even the People's Republic of China has experienced difficulty in establishing fuelwood plantations due to the pilferage of newly planted saplings. Depending on these factors, one or more of the following strategies should be adopted by LDCs to exploit their forests as a renewable resource.

- Fuelwood Plantations. Fuelwood plantations permit close control of the nature and quality of the wood produced. The species planted is selected for its ability to grow quickly, and thus the rotation time can be reduced to as little as 6-8 years.

Annual plantation production can be very high. In most of Africa, eucalyptus plantations have achieved levels of 50 m³/ha./yr. under excellent conditions. More representative figures are 20-70 m³/ha./yr. in South America, and 15-25 m³/ha./yr. in tropical Africa. On drier sites increments may fall to below 10 m³/ha./yr. Due to their high productivity, plantations may reduce the land needed to grow the same

quantity of fuel by as much as one fifth, which would be important where agricultural land is expensive.

There are some disadvantages to fuelwood plantations, however. Since they are monocultures, they tend to be more susceptible to disease. Such intensive use of the land will deplete nutrients and require the use of fertilizers, which should not be diverted from food production in many LDCs.

Fuelwood from plantations is relatively expensive due to high capital and operating costs. For large plantations, costs run \$200/ha./yr. to produce 15 tons of fuelwood, enough to satisfy the cooking needs of 40-50 people. However, village woodlots may be more attractive since the labor now expended in the collection of fuelwood could be applied to a communal plantation, which would reduce costs significantly.* As it can take several years before a plantation produces fuelwood, it will be difficult to resist the temptation to harvest prematurely when fuelwood is scarce.

- Refining and Enrichment. Refining, also known as "timber stand improvement" (TSI), is the cleaning and thinning of natural forests with the object of increasing the proportion of potential final crop timber trees in the stand. The yield of fuelwood may be only 1-2 m³/ha./yr. However, this can be increased by enrichment, which is the planting of more desirable species as thinning occurs.

The advantages of this method compared to plantations are the low capital investment required and the immediate production of fuelwood. However, it does require considerably more land than a plantation to produce the same quantity of wood.

- Secondary Forest Fuels. Secondary forest fuels are the result of the conversion of primary woody material to more valuable fuels by carbonization, distillation, or gasification. The first two processes are of more interest as they produce fuels that are lighter and less bulky than the raw material, and thus can be transported more readily to potential markets. This would allow remote forest regions that are too far from population centers to supply fuelwood to be exploited for their energy.
- Carbonization. Carbonization, or charcoal production, is the chemical reduction of wood. It is the simplest method to upgrade the value of wood as a fuel. More than 70% of the energy content of the wood is retained in the charcoal and the energy content per unit weight is doubled as compared to air-dried wood.

* Arjun Makhijani and Alan Poole, Energy and Agriculture in the Third World. Cambridge, MA: Ballenger Publishing Co., 1975.

As charcoal is smokeless and almost sulfur-free, it is an ideal fuel for domestic use in towns and cities. Charcoal can be a valuable industrial fuel in direct and indirect drying processes, cement production, and even steel production where sufficient supplies are available.*

- Distillation. Wood can be distilled to obtain methanol, acetic acid, esters, acetone, various wood oils, and tars. Noncondensable gases are also given off which can be used as an energy source for the process. Methanol is a very high octane fuel which can be blended with petroleum. However, the yield is small, as one metric ton of wood produces only 14 liters of methanol.**
- Gasification. Wood can be used as a raw material for the production of producer gas (carbon monoxide) and water gas (carbon monoxide and hydrogen). The most efficient use of producer gas is in boilers, since the heat generated by the exothermic process is captured. In 1969 wood-fueled producer gas plants were operating in several LDCs (Kenya, Sri Lanka, India, and West Africa). Water gas can either be burned or used for the synthesis of methanol.***

4.2.2 Biogasification

Biogasification is the anerobic fermentation of organic materials such as crop residues, animal dung, and human wastes, which results in the production of methane. The fermentation reaction is divided into two phases: acidogenic and methanogenic. In the former, acid-forming bacteria break down the complex organic substrate into fatty acids, alcohols, carbon dioxide and hydrogen. The microorganisms of the methanogenic phase convert these simple compounds into methane (CH_4) and carbon dioxide. The net conversion efficiency (BTU methane produced/BTU organic matter added) ranges from about 45-65%.****

Biogasification processes can be classified on the basis of the temperature at which digestion occurs. Mesophilic digestion is the most common process and requires temperatures within a range of 13 to 52°C (optimally between 28 and 45°C) and fluctuating no more than $\pm 2^\circ\text{C}$.***** Thermophilic digestion

* D.E. Earl, Forest Energy and Economic Development. Oxford: Clarendon Press, 1976.

** Ibid.

*** Ibid.

**** Makhijani and Poole, 1975.

***** Vaclav Smil, China's Energy Achievements, Problems, Prospects. New York: Praeger Publishers, 1976.

occurs in the 55 to 60°C range, and is sensitive to very small temperature changes.* The advantage of thermophilic digestion is that it accelerates the digestion reactions, and thus reduces detention time (by about 50%). This has the effect of reducing capital costs since a smaller digester can be used to produce a given quantity of methane.**

In theory, this is perhaps the most attractive technology for energy production in the LDC rural areas. The gas given off by this process contains methane (CH₄), carbon dioxide (CO₂), and traces of hydrogen sulphide (H₂S); thus, the nutrient content of the incoming organic material is retained in the outgoing dung which is used as a fertilizer. Indeed, digested animal dung yields 10-40% more available nutrients compared to composted wastes.*** Thus, biogasification produces energy in a manner which does not compete with, and may even enhance, food production.

Another attractive feature of biogasification is its adaptability: systems can be designed to meet the energy needs of single families or whole communities. Since the beginning of the decade, the People's Republic of China has made much progress in both simplifying this technology and implementing it in rural areas. In May 1977 the New China News Agency reported 4.3 million working units. In Szechwan province alone, 17 million people use biogas for cooking and lighting. In some counties of this province, fully 80% of all rural households are served by biogas.

The most popular type of digester is the water-pressurized tank which is shown in Exhibit 74-a. It has a funnel-shaped loading chamber, rectangular fermentation chamber, and a narrow slag compartment through which the spent material is removed after gas generation. A small 10 m³ digester, which can provide energy for cooking and lighting for a family of five, can be constructed from local materials for \$15-20.**** Larger digesters are constructed using reinforced concrete and the produced gas is used for fueling water pumps and farm processing machinery and small-scale electrical generation.*****

Makhijani and Poole***** describe a more advanced biogas system designed to generate electricity and to provide cooking fuel in rural India. A schematic diagram of this village biogas electricity system is presented in Exhibit 74-b.

* Vaclav Smil, China's Energy Achievements, Problems, Prospects. New York: Praeger Publishers, 1976.

** Makhijani and Poole, 1975.

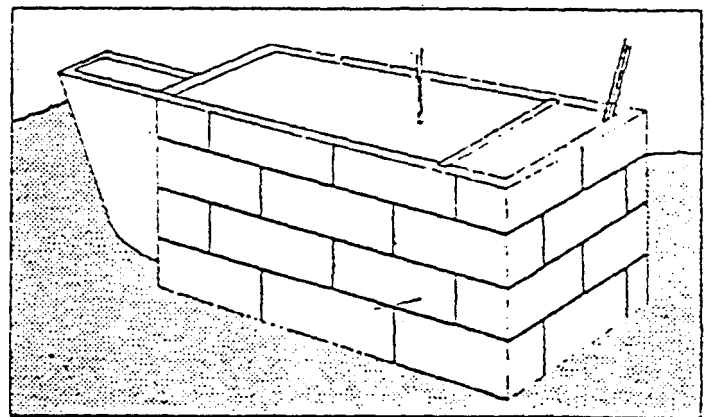
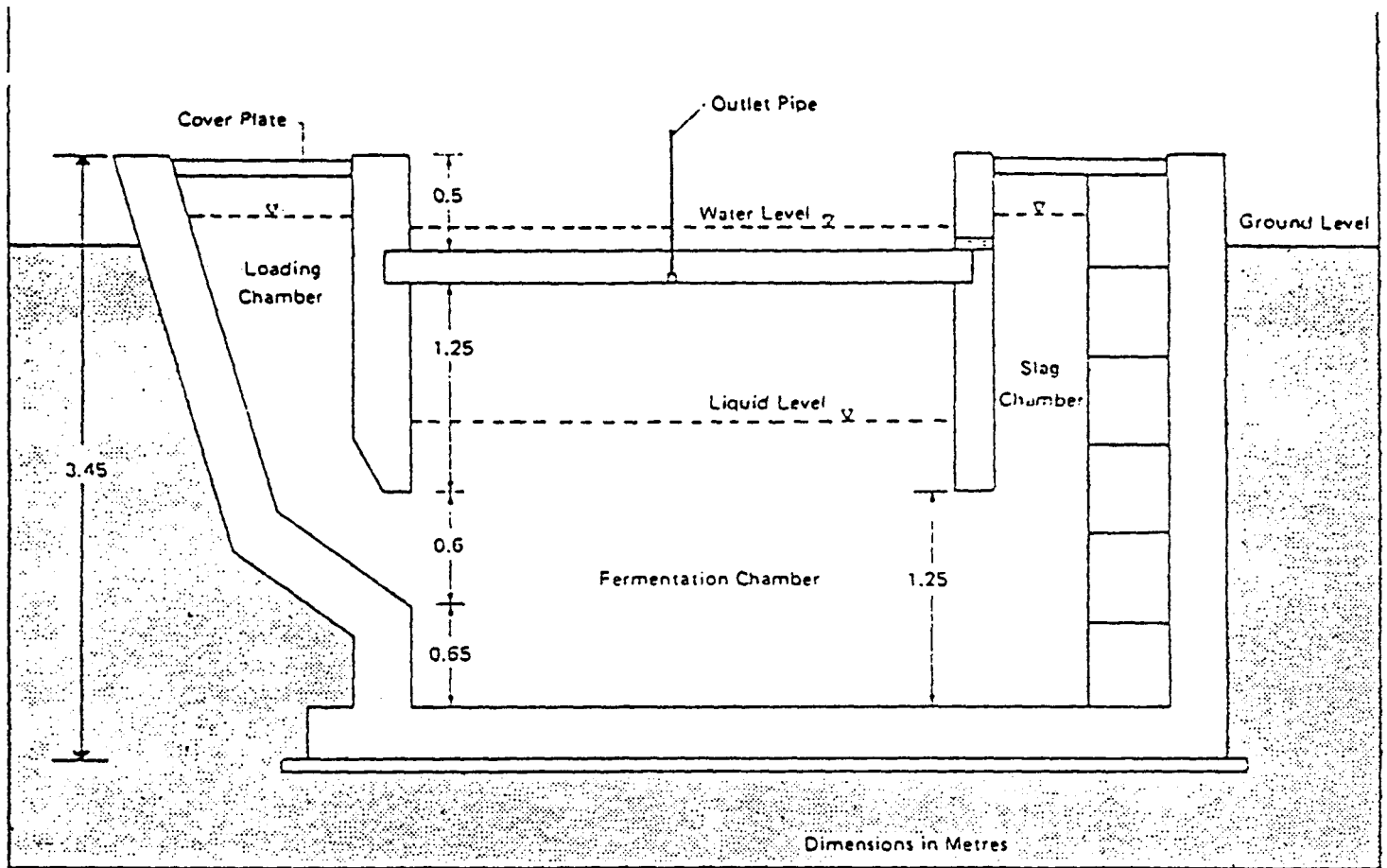
*** A.B. Lanki, WEC M77.

**** Vaclav Smil, "China Claims Lead in Biogas Supply," Energy International, June 1977, pp. 25-27.

***** Vaclav Smil, 1976.

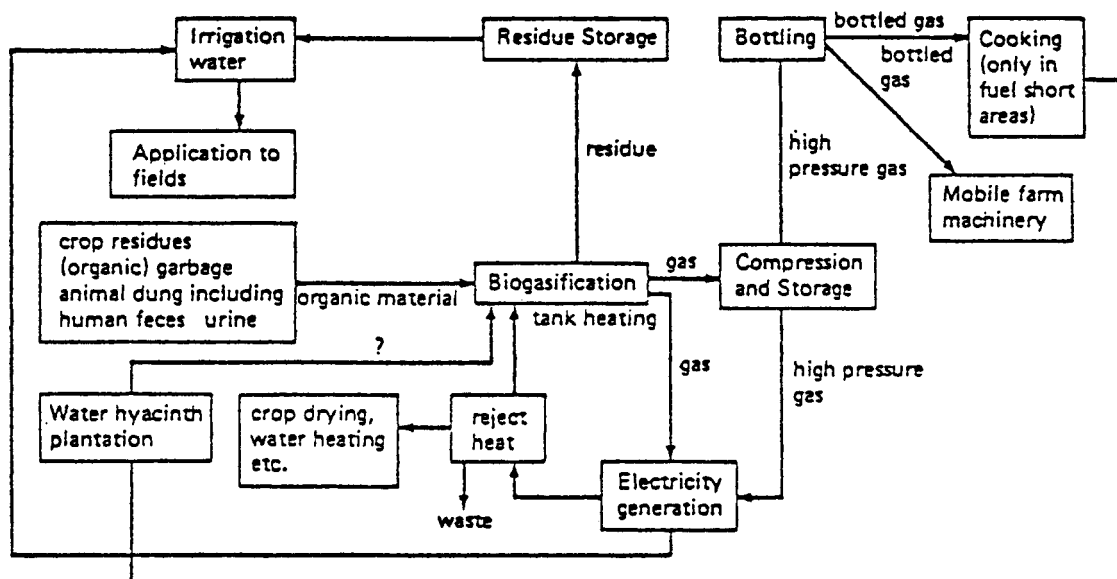
***** Makhijani and Poole, Energy and Agriculture in the Third World. Cambridge, MA: Ballinger, 1975.

EXHIBIT 74-a. WATER-PRESSURIZED BIOGAS SYSTEM FROM THE PEOPLE'S REPUBLIC OF CHINA



Source: V. Smil, 1977.

EXHIBIT 74-b. SCHEMATIC DIAGRAM OF VILLAGE BIOGAS-ELECTRICITY SCHEME SYSTEM



Source: Makhijani and Poole, 1975.

Gas produced by this system would be compressed and stored when not needed to generate electricity. The stored gas could then be used to meet peak electricity needs or, where needed, to supply domestic cooking needs. The waste heat from the generation of electricity could be used to heat the digester. The methane produced could be used to run farm machinery, and the electricity could be used to operate irrigation pumps and to serve domestic needs.

The vegetable and animal wastes required would be purchased from farmers. The prices paid for this material would increase where it is currently used as a fuel.

Such a village biogas system could be operated by a trained villager, with assistance from more highly trained personnel assigned to similar biogas systems in 10-15 villages.

The capital costs of such a system are shown in Exhibit 75. Two cases are illustrated here, one where some of the biogas is used for cooking and the other where all the biogas is used for the generation of electricity. The capital costs per kw of generating capacity (\$460 with, and \$265 without cooking fuel) compare favorably with that of a coal-fired system in India, which would be about \$500 per kw.

Biogasification could prove to be an important source of energy for non-OPEC LDCs, as it is both an ecologically sound and low-cost technology. If the People's Republic of China's experience over the last decade can be taken as an indication of its viability, biogasification can be implemented rapidly on a large scale to help satisfy rural energy needs.

4.2.3 Solar Energy

There is considerable potential for use of solar energy in LDCs provided that the high capital costs for solar devices can be reduced. At present, the technology is available for harnessing the sun's energy to accomplish numerous tasks which would reduce the LDCs' dependence on conventional energy forms and improve their living conditions.

There are currently two types of systems for exploiting solar energy: solar collection systems and photovoltaic systems.

- Solar Collection Systems. Solar collectors capture solar energy in the form of heat (thermal energy). This energy can be used to desalinate water; heat and cool buildings; and to dry grain, fruit and timber.

Concentrating collectors can provide heat in the range of 100-300°C and have the potential for large scale industrial applications in LDCs.* Solar collectors can also be used to power heat

* Denis Hayes, Energy for Development: Third World Options, Paper 15, December 1977.

EXHIBIT 75. CAPITAL COSTS OF BIOGASIFICATION-ELECTRIFICATION SYSTEM
(in 1974 dollars)

	With Cooking Fuel A	Without Cooking Fuel B
Biogasification plant ^a	8,000	8,000
Gas plant auxiliaries	1,000	1,000
Land cost	1,000	1,000
Gas storage and compression ^b	1,500	1,500
Cooking fuel distribution cylinders and gas stoves ^c	8,000	---
Electric generator with reciprocating gas engine and switchgear @\$160/kw installed ^d	12,000	22,500
Construction supervision and training ^e	<u>1,000</u>	<u>1,000</u>
Subtotal	32,500	35,000
Interest on capital during six months' construction @12%	<u>2,000</u>	<u>2,000</u>
Total	34,500	37,000
Cost per kw	\$460	\$265

^aTwo digestors, each producing 140 cubic meters of biogas per day are assumed. The gas production in columns A and B is the same. Exclusive of the energy use in the biogas plant, the digestors will produce about 2 billion BTUs of fuel per year.

^bStorage for 50 percent annual production of unscrubbed gas.

^cIncludes \$6,000 capital cost for market town headquarters for 12 villages.

^dBased on mid-1974 quotation from a manufacturer in the U.S.A. and includes approximate shipping costs. In the scheme with cooking fuel we have 75kw generator (Col. A); without cooking fuel the entire output of the gas plant goes to the 240 kw generator. A gasoline engine or diesel engine can be substituted for the gas engine.

^eColumn A assumes all 200 families in the village use methane for cooking, \$6,000 for cylinders, \$2,000 for stoves. Column B assumes zero use.

Source: Makhijani and Poole, 1975.

engines. Irrigation pumps using this technology are being manufactured commercially in both the United States and France. Although the costs of these devices are now high, they are expected to drop with the introduction of mass production and design improvements.*

- Photovoltaic Systems. In photovoltaic systems, incident solar energy is converted into electrical energy by means of an array of photovoltaic cells. There are several features of this type of system that would serve the needs of LDCs: no moving parts, zero fuel consumption, low maintenance, longevity, and modularity (if one piece of the system fails, the rest can continue to function). This system is best applied in a decentralized plan in order to maximize utilization of the heat that is also collected.

The disadvantage of this system, and of any solar system, is that it can only operate intermittently unless some method for storing the electricity generated during the day is provided. This can be done with batteries, and research is being conducted to test the feasibility of storing the hydrogen energy generated from the electrolysis of water during peak hours.

The factor that will determine whether photovoltaic systems can be viable sources of energy for LDCs is their cost. Recent technological advances in the manufacture of photovoltaic cells should result in a drastic reduction in their cost. At present these devices are priced at \$13.50 per peak watt, and this cost is expected to fall to \$1-2 by 1980, \$.50 by 1986, and \$.10-.30 by 1990.**

* D Hayes, 1977.

** Ibid.

5. CHARACTERISTICS AND LIKELY RANGES OF RESPONSE OF LDC COUNTRY GROUPS

In choosing among the possible responses to their energy financing problems, LDCs will be influenced by a number of factors, including their energy and mineral resource base, the level and distribution of their economic development, and the severity of their financing problems. In order to provide some indication of the differing positions and hence responses of the five groups of countries addressed in the Executive Summary (a list of their socio-economic indicators was provided in Exhibit 57), each of the groups is briefly discussed in terms of its likely range of response to the energy situation.

5.1 INDUSTRIALIZED COUNTRIES

In each of the nine countries categorized as "industrialized," industrial activity accounts for a higher contribution to GDP than agricultural activity (Exhibit 76). Also, compared to other LDCs, they have relatively less traditional handicraft production and relatively more "modern" industry. However, their modern (and predominantly urban) industrial sector is usually independent of the traditional urban and rural sectors; and, as in other LDCs, the social infrastructure and corresponding services have not increased at a rate commensurate with their economic growth. The industrialized LDCs have the highest median GNP per capita per year (\$1120), the lowest crude death rate and infant mortality rate (8 per 1000), the longest life expectancy (70 years), and the most even income distribution (top 5% receiving 20%, lowest 20% receiving 4%) of any group. They also have the highest percentage of their populations located in urban areas (57%) and, not surprisingly, the highest commercial energy consumption per capita (1220 kgce).

Measuring the industrialized group against the developed countries puts their "affluence" into perspective: their median GNP per capita is less than one-fourth that of developed countries. Their literacy rates (ranging from 68% in Brazil to 94% in Spain) are significantly lower than developed countries (99%). The poorest 20% of the population in this group of countries receives 4% of the income compared to 5.7% in developed countries, while the top 5% of their populations receives 20% of the income versus 15.5% in the developed countries.

EXHIBIT 76. INDUSTRIALIZED LDCs -- % GDP, 1973

	<u>Agriculture</u>	<u>Industry*</u>	<u>Services</u>
Argentina	12.3	45.7	42.0
Brazil	17.4	28.9	54.7
Chile	6.5	37.9	55.6
Korea, Rep. of	28.1	32.1	37.6
Singapore	2.7	35.1	62.6
Spain	12.6	35.1	52.3
Uruguay	17.5	28.0	54.6
Yugoslavia	18.4	44.6	37.0
Taiwan	27.0	45.9	27.2
Developed Countries	3.2	39.5	56.6

Source: World Bank World Tables 1976

* Includes manufacturing and mining

The group shares other similarities. All are coastal nations with significant trade activities (most notably Singapore). Also, each has relatively easy access to foreign capital markets. In fact, these are virtually all of the oil importing countries which were identified in Chapter 2 as having had access to the Eurocurrency market in 1976-77.

There are also substantial differences among the countries within the industrialized group, as shown by the ranges for annual GNP per capita (\$2490 for Spain versus \$390 for the Republic of Korea), the percent of population living in urban areas (39% in Yugoslavia versus 100% in Singapore), and the crude death rate per 1000 (the 9.3 in Uruguay is almost twice Taiwan's 4). Other social measures such as infant mortality rates, life expectancy, and income distribution vary widely from country to country within the group, as do their respective natural resources and relative distribution of exports.

As in the other oil importing groups, all of the industrialized LDCs consume more energy than they produce.* However, their relative dependence on imports and the nature of their indigenous energy resources vary considerably. Singapore and Uruguay are most dependent on imports, each producing less than 5% of their consumption needs, while Argentina is the most self-sufficient, currently producing 93% of its total commercial energy requirements (including all of its liquid fuel needs). With respect to solid fuels (coal and lignite), Chile is a net exporter, Korea is virtually self-sufficient, and Spain and Yugoslavia produce over 70% of their needs.**

Probably the most important point for this group is that despite their energy intensity of industrialization relative to other sectors, this group uses substantially more energy per capita than any other LDC category, and (except for Argentina and, because of its position as a major international refining center, Singapore) is extremely vulnerable to disruptions in oil imports. Thus, the group as a whole probably has the least incentive of any oil importing LDC group to change its development strategy radically in response to the energy situation for a number of reasons. These include their high level of present investment in industry and infrastructure and their relative financial strength and access to international credit. Probably equally important is the impression among the leadership in most of these countries that industrialization has "worked" for them and the vested interest, not only of the leadership but also of the gradually broadening urban/industrial upper and middle classes, in continuing such industrialization.

As a result, like the developed countries, the industrialized LDCs generally can be expected to respond to the energy situation by: (1) effecting such intrasectoral energy conservation as is possible without endangering the

* United Nations, World Energy Supplies 1971-75, 1977.

** See Exhibit 77.

EXHIBIT 77. 1975 PRODUCTION AND CONSUMPTION OF COMMERCIAL ENERGY
(In Million Metric Tons - Coal Equivalent)

<u>Country</u>	<u>Total</u>			<u>Coal & Lignite/Solid Fuels</u>			<u>Crude Liquid Gas/Liquid Fuels</u>		
	<u>Production</u>	<u>Consumption</u>	<u>P/C</u>	<u>Production</u>	<u>Consumption</u>	<u>P/C</u>	<u>Production</u>	<u>Consumption</u>	<u>P/C</u>
Argentina	41.593	44.517	.93	.502	1.537	.33	31.081	31.227	.99
Brazil	25.405	71.793	.35	2.717	4.937	.55	12.782	56.931	.22
Chile	4.716	7.843	.60	1.362	1.147	1.19	2.488	5.829	.43
Korea, Rep. of	17.800	35.980	.49	17.593	18.367	.96	-	17.407	0
Singapore	-	4.839	0	-	.001	0	-	4.838	0
Spain	20.369	76.171	.27	12.429	16.825	.74	3.296	53.045	.06
Uruguay	.139	2.886	.05	-	.041	0	-	2.706	0
Yugoslavia	28.212	41.208	.68	18.068	20.592	.88	5.450	15.892	.34

EXHIBIT 77. (cont'd.) 1975 PRODUCTION AND CONSUMPTION OF COMMERCIAL ENERGY
(In Million Metric Tons - Coal Equivalent)

<u>Country</u>	<u>Natural Gas</u>			<u>Hydroelectric - Nuclear</u>		
	<u>Production</u>	<u>Consumption</u>	<u>P/C</u>	<u>Production</u>	<u>Consumption</u>	<u>P/C</u>
Argentina	9.062	10.805	.84	.949	.949	1.00
Brazil	1.050	1.050	1.00	8.855	8.875	.99
Chile	.111	.111	1.00	.755	.755	1.00
Korea, Rep. of	-	-	NA	.207	.207	1.00
Singapore	-	-	NA	-	-	NA
Spain	.002	1.762	.001	4.643	4.539	1.02
Uruguay	-	-	NA	.139	.139	1.00
Yugoslavia	2.318	2.318	1.00	2.376	2.406	.99
Taiwan*						

* No data available

Source: UN, World Energy Supplies, 1971-1975, 1977

continued development of the modern industrial sector or overly antagonizing the general populace, and (2) "spending their way out" of the situation by investing substantially in increasing exports, developing new indigenous supplies, or both. These general projections are supported by an examination of the policies being followed by the largest Latin American country and the largest East Asian country in the group: Brazil and the Republic of Korea.

Both Brazil and the Republic of Korea have chosen to follow a path of rapid economic growth and concentration on increasing their industrial development. The work force split is virtually identical: 44% of their respective populations are engaged in agriculture and mining activities, and 18% to 20% in manufacturing activities. An increasing portion of their energy related industries are either government controlled or substantially regulated. However, the differences in their rate of economic growth, natural resources, access to capital, and energy consumption patterns dictate different energy strategies. For example, Brazil's program to substitute alcohol for gasoline has been developed because its transportation sector consumes 44% of Brazil's total energy requirements; South Korea subsidizes coal prices because 43% of her energy needs are in the commercial-residential sector, largely coal for home heating purposes.

Brazil's immense agricultural export base, abundance of water power, extensive minerals deposits (primarily iron ore, bauxite, and manganese), and largely unexploited timber and other resources of the North make her a potentially wealthy country even without substantial industrialization. Still, Brazil has focused on industrialization as its main "engine of growth," primarily by pursuing an "import substitution" policy to build the capacity to serve its sizeable domestic market. At the same time, it also has tried to strengthen its agricultural export base and to develop its northern territory (Brazil is one of many LDCs which, rather than facing population pressures on the land, is endeavoring to grow into the territory it has). The process of industrialization and concomitant development is far advanced: Brazil has 25 cities of over 500,000 population, relatively well-developed transport and electric power, and a complex industrial base (including, for example, its own automobile, railroad, and military aircraft production capabilities).

Unfortunately, from an energy point of view, Brazil is not so well off. Her hydroelectric resources are located far from urban/industrial centers, her coal is of poor quality, and her oil discoveries so far have been limited. In 1975 Brazil imported 65% of her total commercial energy needs and 80% of her oil needs; in 1976 Brazil's oil bill alone equalled 40% of her export value. As the debt service as a percent of exports is rising rapidly (from 39% in 1974 to an estimated 60% in 1978), Brazil has used incoming foreign capital to compensate for its growing trade deficit rather than for development projects.

To decrease this drain on her economic growth, Brazil has formulated a capital intensive energy strategy that focuses on readily achievable conservation of petroleum, development of indigenous resources, (including coal, secondary recovery from existing oil fields, exploration for new oil and gas, hydropower for nearby minerals processing and for connection to a national grid, uranium, and production of methanol from sugarcane), and the development of

of nuclear power. A major element of Brazil's strategy is to negotiate investment and/or risk-sharing contracts with private companies (predominantly multinationals) both to develop new energy supplies and, where possible, to pursue industrialization near hydropower resources (e.g., for aluminum reduction). At the same time, there is evidence that as an agricultural exporter who has suffered from a high degree of instability in its export receipts (most recently, from the dramatic decline in the price of sugar), Brazil has tried to pursue a strategy of price stabilization -- most recently, by buying up a portion of other countries' coffee stocks.

In short, Brazil has responded by trying to invest whatever is necessary to protect its industrial growth, and if possible, to protect or increase its export receipts. This has meant a concentration on capital intensive energy resource development rather than changes in the pattern of economic growth. For example, Brazil's attempt to double her hydroelectric capacity in the next decade will cost an estimated \$20 billion, (one-third of the world's projected investment in power dams). Her alcohol substitution program (which theoretically calls for the ratio of alcohol in gasoline to rise from its present 3% to 100% by 1985) will require a ten-fold increase in alcohol production by 1980 and another 600% increase by 1985, with a total investment estimated at \$20 billion. Investment in her nuclear power plant and electrification extension programs could equal these amounts.

Unlike Brazil, the Republic of Korea has few natural resources. Although she possesses an abundant supply of anthracite coal, it is of generally poor quality, and her hydroelectric power is still a relatively insignificant source of energy. What the Republic of Korea lacks in natural resources, however, it compensates for in its exceptionally strong industrial export base. Through her strategy of export promotion, incentives, and subsidies (including subsidized electric power and coal at artificially low, price-controlled rates), she has achieved a phenomenal growth in GNP and exports in the past 15 years. In 1961, 78% of Korean exports were primary products -- mainly tungsten, coal, seaweed and fish; by 1971, 86% were manufactured products. Total exports expanded more than 40 times between 1961 and 1972; manufacturing exports expanded more than 170 times in the same period.* This rapid growth has led to a decreasing debt service as a percent of exports and an estimated \$150 million surplus in 1977. The Republic of Korea is viewed as a good investment risk and has had little difficulty in attracting foreign loans to help finance her investment projects.

This country's stated economic objective is to achieve a continued rate of GNP growth of 9.2%, primarily by the continued expansion of exports. The Republic of Korea intends to maintain this growth in the face of the price of oil imports, primarily by achieving sufficient export earnings to pay for her imports rather than by cutting back significantly on the use of petroleum.**

* Frank, Kim, Westphal, Foreign Trade Regimes and Economic Development: South Korea.

** The major exception is in transportation, where Park's regime has strictly limited the ownership of private automobiles and has promoted the use of mass transit.

Indeed, petroleum is projected to represent a higher fraction of her primary energy use in 1981 than in 1974 (58.5% vs. 52.4%). At the same time, like Brazil, Korea plans substantial investment in energy resource development, including nuclear power (\$1.5 billion over the next five years), offshore oil exploration, and the expansion of coal production.

Both countries essentially appear to plan to continue their "status quo" development trends, with additional emphasis on the development of indigenous energy resources. We believe that this is likely to be the general pattern of the industrialized LDCs as a group. Of course, there is likely to be some modification of historic trends for other reasons. Both Brazil and the Republic of Korea, for example, have felt constrained to include the achievement of more equitable distribution of income among their primary economic goals. There is substantial evidence that Korea, partly to achieve a comparative export advantage in view of its skilled but relatively low-paid labor base and partly to expand economic opportunities, has tended to foster increasingly labor-intensive industrialization over-time. Countries in less secure financial positions face practical limits on their rates of borrowing (limits which may force even Brazil to re-think its strategy). Nevertheless, the basic direction of this group is to continue what has worked in the past.

5.2 BALANCED GROWTH ECONOMIES

The eight countries within this category have diverse and relatively substantial resource bases, but do not have so specialized an infrastructure as to commit them to a particular development course. This category is therefore unique among LDC groups in that it has considerable flexibility in choosing its future development strategies.

Since energy consumption can be substantially reduced by making inter-sectoral as well as intra-sectoral shifts in economic activity (see Section 4.1), the countries within the balanced growth category are capable of a broader response to the energy situation than are other LDCs. Their potential responses include such redirections of development priorities as inter-sectoral shifts in economic activity, income redistribution, and intra-sectoral conservation measures.

It does not, however, follow that countries with balanced economies necessarily have the greatest potential to overcome the energy impediments to their continued economic growth. Nations in this category are differentiated from the industrialized LDCs insofar as they have attempted industrialization, but have lacked the resources necessary for full-fledged success. Thus, unlike the industrialized group, they do not have the option of "buying their way out" of an energy shortage. On the other hand, because their economies are far more complex than those of many other LDCs, they require more complex social and economic changes in order for an energy shortage to be significantly alleviated. In order to realize the full potential of energy conservation, these countries would have to intervene simultaneously in a wide range of sectors and aspects of economic activity. The organizational magnitude of this task would drain already scarce resources from other development priorities.

The predominant feature of the economic structures of the balanced countries is that at the present time, no single sector is clearly the leading economic sector in terms of its overall contribution to these countries' GDP (see Exhibit 78.). The absence of a single dominant economic sector within these countries is generally indicative of attempts (with various levels of success) by individual countries to implement import substitution policies through the development of a "mixed" economy.

EXHIBIT 78. BALANCED GROWTH ECONOMIES' SECTORAL CONTRIBUTION TO GDP, 1973

	<u>Agriculture</u>	<u>Industry*</u>	<u>Services</u>
Colombia	29.6	27.5	42.8
Greece	20.9	32.5	47.4
India	47.8	21.1	31.3
Pakistan	35.8	21.5	42.7
Panama	16.3	25.3	58.3
Peru	15.0	36.6	48.4
Philippines	36.4	27.8	35.8
Turkey	27.3	30.1	42.3

* Includes World Bank categories, Manufacturing plus Other Industry

Source: World Bank, World Tables, 1976.

Import substitution as a developmental economic policy leads to the creation of a mixed economy, in that the country aims to develop the necessary industries and services to allow it to be essentially self-sufficient. In the traditional pattern, the initial phases of import substitution focus on the indigenous production of "light" consumer goods, followed by the substitution of domestic production for imports in middle range products (e.g., paper and paper products, some chemicals, etc.). The final phases of an import substitution policy focus on developing the remaining heavy industries such as iron and steel, petrochemicals, etc.*

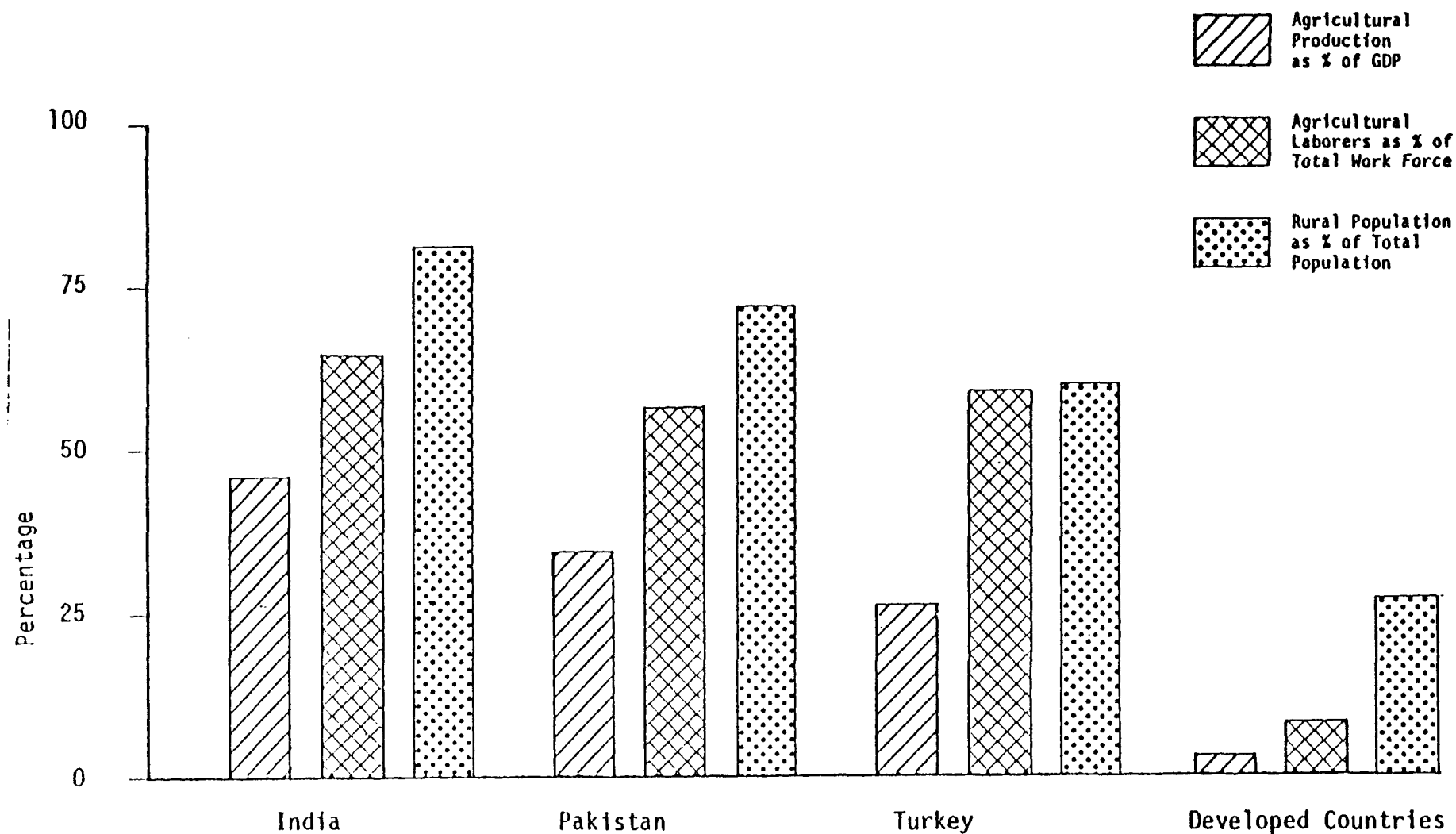
* OECD Development Centre, Choice and Adaptation of Technology in Developing Countries, Paris, 1974.

The creation of a heavy industrial base is the most difficult phase in an import substitution development strategy, due to the highly capital- and energy-intensive nature of the types of industries that are involved. While the light and intermediate industrial sectors can be built up without unduly stressing the traditional economy, this final phase requires the commitment of unprecedented levels of financial resources to build and operate the basic industries. The financial strain that this places on the countries' economies is aggravated by the fact that the heavy industries, by nature of their capital intensity, require a larger financial input (which must be generated in other sectors of the economy) than they can reinject into the economy through increased employment levels. Further, since the basic industries do not make any significant direct contribution to improve the quality of life for the average person, this final phase is often seen as essentially a financial sink which accounts for little "real" economic growth, defined in human terms.

Most of the countries within the balanced growth economies category have already completed the primary and intermediate phases of import substitution, and are attempting, often unsuccessfully, to embark upon the final stage of becoming self-sufficient in the heavy industrial sector. Colombia, for example, had accomplished the primary and intermediate phases of import substitution by the mid-1960s, and thereafter began to build a heavy industrial base. However, in terms of traditional economic indicators, Colombia's attempts to create a heavy industrial economy represented negative economic growth. Direct and indirect employment, foreign exchange earned and saved by domestic manufacture, and the linkage effects on the rest of the economy were all significantly worse in the heavy industrial economy than they would have been had equivalent investments been made in the more traditional labor-intensive, export-oriented industries such as textiles, clothing, footwear, glass products, or even some light metals.* Similar experiences have occurred in all of the other countries in this category, but most particularly in India and Turkey where the failure of recent heavy industrialization policies to meet the expectations of the general populace for a rising standard of living has led to widespread discontent with the existing political regimes.

The failure of the advanced import substitution growth policy to meet basic human needs within the balanced countries is appallingly evidenced by the demographic characteristics of those countries. All of the countries in the group are still essentially agrarian societies in that the agricultural sector is of primary importance in determining the economic and social well-being of the population. As Exhibit 79 illustrates, agricultural production still absorbs well over half of the total work force in India, Turkey, and Pakistan. In addition to direct agricultural labor, the rural sector provides employment opportunities in the service and cottage industries sectors, so

* David Morawetz, "Import Substitution, Employment, and Foreign Exchange in Colombia: No Cheers for Petrochemicals," in C. Peter Timmer, et al., The Choice of Technology in Developing Countries, Harvard University, 1975.



Sources: Statistics on agricultural laborers as % of total work force based on figures from FAO Production Yearbook, 1976. Others based on World Bank World Tables, 1976.

that the vast majority of the population resides in and is dependent upon the rural economy. Nevertheless, unemployment problems are severe in the rural sector. This is partly due to the lack of multiple cropping in most LDCs and the resultant disparity between the peak labor requirements of the harvest and the limited need for labor during the remainder of the year. The Indian Bhagavati Unemployment Commission has estimated that among the totally unemployed in 1971, 85% were located in the rural areas. In addition, 87% of those who worked less than 28 hours per week, and 86% of those who worked less than 14 hours per week, were located in the rural sector.*

Primarily as a result of the extremely high rural unemployment rate and the somewhat specious expectations among the population for employment opportunities in the industrial sector, the balanced growth countries have experienced a major demographic shift from rural to urban areas over the past few decades. On average, the urban population among LDCs is increasing at a rate of 5% per year, or nearly twice as fast as the already high growth in total population.** At this rate, the urban population will double in fourteen years.

Urban unemployment is generally high among the balanced growth countries and will continue to increase as the agricultural refugees migrate to the cities. Employment in the urban sector is primarily a function of the modern industrial sector, which must grow at a rate of 7-8% per year in order to expand industrial employment even 5%*** In countries such as Colombia (whose urban population comprises 63% of the total population) or Turkey (which is 42% urbanized with a present unemployment rate of 9%),**** it is obvious that urban areas will not be able to absorb and adequately provide for the burgeoning population.

In addition to the historic failure of the industrial sector to expand sufficiently to keep pace with the general populace's growing requirements for more jobs, the industrialization policies pursued by the balanced growth countries have also failed to make significant contributions to the direct satisfaction of the basic human needs of the populations. The major benefits from industrialization in terms of wealth, infrastructure, and employment, accrue primarily to the small percentage of the total population which resides in the modern urban sector. Thus, although the balanced countries category as a whole registers a higher per capita income than most of the other categories of LDCs, the distribution of income within the countries'

* The Economist Intelligence Unit, Quarterly Economic Review of India, Nepal: Annual Supplement 1976, 1976.

** World Bank Paper, Urbanization, June, 1972.

*** Makhijani & Poole, Energy and Agriculture in the Third World, Ballinger Publishing Co., 1975.

**** Economist Intelligence Unit, Quarterly Economic Review of Turkey: Annual Supplement 1977, 1977.

economies is skewed and the quality of life for the average person remains quite low. In India, for example, the lowest 30% of the population in terms of income accounted for only 13.5% of total private consumption in 1973/1974. This same segment had an average per capita consumption of Rs 25/month, compared with the Rs 40.6/month which the Indian government has designated as the poverty line.* And, the populations within most of these countries have short life expectancies and high infant mortality rates. In addition, access to some of the "luxuries" of life (e.g., electricity, medical care, transport, education) is severely restricted for the vast majority of the population due to the lack of adequate infrastructure. In the Philippines, for example, only 6.9% of the rural dwellings are electrified, compared with 60.4% of the urban dwellings.**

5.2.1 Energy Consumption***

Current trends in energy consumption among the balanced growth countries represent one more example of their shift in economic emphasis from the traditional agricultural to the modern industrial sector. As a consequence of their attempts to establish a heavy industrial base among the primary industries, the balanced growth countries have had to substantially increase their consumption of commercial energy, particularly oil. Since most of these countries do not have significant developed indigenous oil resources, almost any increase in their installed industrial capacity commits them to ever-rising import levels. This has placed an unprecedented financial strain upon these LDCs economies and has significantly decreased the availability of investment funds to foster further development. The use of these valuable commercial fuels as industrial process inputs denies the agricultural and residential/commercial sectors both the types and quantities of energy inputs they require to keep pace with the basic needs of an expanding populace.

Sectoral energy consumption in the LDCs can best be addressed in terms of two general categories: the urban industrial sector (which includes industry and transport energy consumption), and the rural-agricultural sector (including agriculture and residential energy consumption). This approach is useful in that it reflects the more general dichotomy that exists within the LDC economies between the traditional and modern sectors. It therefore portrays the energy implications of the current development strategies which emphasize the shift from a traditional to a modern economy.

* Economist Intelligence Unit, Quarterly Economic Review of India, Nepal: Annual Supplement, 1976, p. 6.

** U.N., Statistical Yearbook, 1975.

*** See Exhibit 80.

EXHIBIT 80. BALANCED GROWTH ECONOMIES 1975 PRODUCTION
AND CONSUMPTION OF COMMERCIAL ENERGY
(In Million Metric Tons - Coal Equivalent)

Country	Total			Coal & Ignite/Solid Fuels			Crude Liquid Gas/Liquid Fuels			Natural Gas			Hydroelectric - Nuclear		
	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C
Colombia	19.111	15.800	1.20	3.200	3.183	1.00	12.176	8.890	1.36	2.481	2.481	1.00	1.255	1.255	1.00
Greece	6.156	18.909	.05	5.909	6.510	.91	-	12.151	0	-	-	NA	.247	.248	.99
India	114.624	132.054	.86	96.820	96.383	1.00	12.176	30.042	.40	1.216	1.216	1.00	4.413	4.413	1.00
Kenya	.000	2.325	.03	-	.046	0	-	2.167	0	-	-	NA	.000	.112	.70
Pakistan	8.198	12.825	.63	.770	.844	.91	.566	5.118	1.10	6.198	6.198	1.00	.664	.664	1.00
Panama	.814	1.442	.01	-	.016	0	-	1.423	0	-	-	NA	.014	.003	4.66
Peru	6.793	10.654	.63	.005	.359	.23	5.360	8.955	.59	.572	.572	1.00	.769	.769	1.00
Philippines	.562	13.849	.04	.105	.128	.02	-	13.263	0	-	-	NA	.457	.457	1.00
Turkey	12.434	24.701	.50	7.160	7.252	.98	4.550	16.713	.27	-	-	NA	.724	.736	.98

Source: U.S. World Energy Supplies 1971-1975, 1977.

EXHIBIT 81. SECTORAL ENERGY CONSUMPTION IN INDIA*

	% of Total Energy Consumed	% of Total Commercial Energy Consumed	Average Annual Sectoral Growth Rate in Commercial Energy Consumption (%)
Agriculture	11	3	9.9
Industry	24	52	7.5
Transport	15	32	6.6
Residential	50	13	6.2

-
- * India will be used throughout this discussion of balanced countries' energy consumption as a representative example of the countries within this category. We feel that this is a valid example both because India has pursued the typical development pattern of import substitution followed by most of the balanced countries, and also because India is one of the major LDC energy consuming countries. India's energy sector is therefore, almost by definition, typical of the LDC energy situation in general.
-

As Exhibit 81 indicates, the urban industrial sector accounts for 84% of commercial energy consumption within India, and is growing at a rate of approximately 7% per year. In terms of specific fuels, the urban industrial sector consumed 96% of the coal, 78% of the oil, and 73% of the electricity consumed by India in all economic sectors.*

Clearly, the urban industrial sector is the driving force in the Indian commercial energy economy. At current growth rates the demand for commercial energy sources to fuel the urban industrial sector will double in ten years. The fuel mix necessary to meet future industrial requirements could vary significantly from country to country, or within a single country over time, as their indigenous energy resource bases are more fully developed or as new energy-saving or fuel-switching technologies are introduced (see Section 4-1).

* Brookhaven National Laboratory.

The rural-agricultural energy sector, which includes all of India's domestic energy requirements (urban and rural) as well as its energy inputs to agricultural production, accounts for substantially more than half of the total energy she consumes. However, since this sector is still fueled primarily by traditional noncommercial energy sources such as animal power, firewood, animal dung, and agricultural residue, only 16% of the total commercial energy is consumed in this sector. Most of it goes to meet the domestic energy requirements of the economically privileged urban population.

As noncommercial energy resources are used predominantly to meet the cooking, heating, and lighting requirements of the rural population and the urban poor, increases in noncommercial energy consumption are tied directly to population increases. With an average population growth rate of 2.5% per year, total noncommercial energy consumption will double every 28 years. At this extremely high rate of population increase, noncommercial energy supplies are rapidly being depleted,* particularly firewood, which supplies approximately one-half of the country's total noncommercial energy. India's present annual consumption of firewood is estimated to be 150 million tons, which represents an annual depletion rate of 12.6% of the total resource base. If this trend continues, India's forests will be entirely consumed in eight years. Therefore, the Indian government is attempting to encourage its rural population to conserve firewood by using more efficient heating and cooking devices, replenishing the forest stock through planting programs, and substituting kerosene for firewood whenever feasible. This last option is of questionable impact, however, since the mitigation of pressure on the forests is achieved only by increasing India's reliance on expensive and scarce crude oil products.

While it is still very small, commercial energy consumption in direct agricultural production is rapidly increasing. Only 3% of the total commercial energy use in India is currently consumed in the agricultural sector, yet this figure is increasing at an average annual rate of close to 10%. The primary fuels used in the agricultural sector at the present time are diesel oil (which is used to fuel small tractors and other farm equipment such as irrigation pumps) and electricity (which is used primarily to operate irrigation pumps). Increases in commercial energy consumption in the agricultural sector are thus related primarily to the increased mechanization of agricultural production.

Another major component of agricultural energy consumption derives from the growing need for artificial fertilizers. The energy resources which go into the creation of synthetic fertilizers are generally accredited to the industrial sector (where the fertilizers are produced) rather than the agricultural sector (where they are consumed). Nevertheless, the increasing

* Except for firewood, traditional noncommercial fuels are available on an annually renewable basis. However, in order to continue to supply the growing population with a constant per capita level of energy from the consumption of dung or crop residues, the animal population and agricultural production would have to increase at least as rapidly as the human population, a prospect which is less than likely to occur.

application of high-potency synthetic fertilizers, derived from the need for increased soil productivity and multiple croppings in order to adequately feed the growing population as well as the developing urban sector, will increase the overall energy intensity of the agricultural.

5.2.2 Summary

The balanced economy countries are becoming aware of the necessity for an effective energy management plan which will integrate their projected energy supply situations with their future energy requirements, given the nature of the development strategies they are pursuing. There are a number of options available to all countries in formulating a development plan, including the intensive development of indigenous energy resources, the implementation of energy conserving or fuel-switching technologies, or the development and utilization of alternative and renewable energy resources including solar, geothermal, and biogas.

The countries within the balanced economies category have another possible option which is potentially of greater significance. That is the option of restructuring or redefining their present development strategies to emphasize more labor intensive, energy conservative sectors of the economy. This option is perhaps uniquely available to the countries within the balanced economies, given that this group is particularly flexible in terms of its diverse resource bases and the level of infrastructural development within its present economies. In fact, some of the countries within the category, including Turkey and India, have indicated that they are re-evaluating their import substitution policies, indicating a slight shift in emphasis in favor of the agricultural and light industrial or consumer goods sectors. This slight redirection of economic policies has been instigated largely by the failure of an import substitution policy to satisfy the basic human needs of the population. However, since social welfare problems are to some extent related to the same economic policies which have tended to increase their productive sectors, energy intensity, a socially-oriented growth policy might also be the most energy-efficient policy.

5.3 PRIMARY EXPORTERS

The primary exporters group consists of those LDCs whose main source of economic growth is the export of primary minerals: Botswana, Guinea, Guyana, Jamaica, Liberia, Mauritania, Morocco, Sierra Leone, Togo, Zaire and Zambia.

As a group, the primary exporters vary considerably from the industrialized and balanced economy LDCs. Their mean annual GNP per capita figure (\$458.3) is considerably lower and they consume considerably less commercial energy. As would be expected, their export figure, as a percentage of GNP, is higher than the other LDCs. Their infant mortality rate is extremely high (96.02 per 1,000 births) and their mean life expectancy is low (48.1 years). In these respects they are much like the agriculturally oriented LDCs. However, the group itself is not totally homogeneous. For example, Guyana has

EXHIBIT 82. PRIMARY EXPORTERS', 1975 PRODUCTION AND
CONSUMPTION OF COMMERCIAL ENERGY
(In Million Metric Tons - Coal Equivalent)

Country	Total			Coal & Ignite/Solid Fuels			Crude Liquid Gas/Liquid Fuels			Natural Gas			Hydroelectric - Nuclear		
	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C
Botswana*															
Guinea	.004	.405	.01	-	-	NA	-	.401	0	-	-	NA	.004	.004	1.00
Guyana	-	.081	0	-	-	NA	-	.081	0	-	-	NA	-	-	NA
Jamaica	.016	2.895	.01	-	.001	0	-	2.870	0	-	-	NA	.016	.016	1.00
Liberia	.039	.690	.05	-	-	NA	-	.650	0	-	-	NA	.039	.039	1.00
Mauritania	-	.143	0	-	.006	0	-	.137	0	-	-	NA	-	-	NA
Morocco	.906	4.75	.19	.652	.734	.88	.029	3.792	.01	.089	.089	1.00	.135	.135	1.00
Sierra Leone	-	.318	0	-	-	NA	-	.318	0	-	-	NA	-	-	NA
Togo	-	.145	0	-	-	NA	-	.145	0	-	-	NA	-	-	NA
Zaire	.646	1.949	.33	.090	.437	.02	.141	1.072	.11	-	-	NA	.415	.440	.94
Zambia	1.545	2.470	.62	.814	.091	.91	-	.887	0	-	-	NA	.731	.692	1.05

* No data available.

Source: UN, World Energy Supplies 1971-1975, 1977.

a much larger percent of her population in urban areas (40%) than Togo (15%) or Botswana (12.3%), has a fairly low infant mortality rate (49 per 1000 births), and a relatively high life expectancy (67.9) in relation to the rest of this group. In-group infant mortality is as high as 127 per 1000 births (Togo) and life expectancy as low as 38.5 years (Mauritania). Guyana, Jamaica, and Surinam all consume much larger amounts of commercial energy per capita than the others in this group, particularly Guinea, Mauritania and Togo (Exhibit 82).

Each country in this group has an ocean port(s) except for Botswana and Zambia. They are both heavily dependent on intercountry transportation systems (rail and road) and cooperation so that their goods can reach a port.

While each country in this group is rich in mineral resources, some have more than others. Guyana, Jamaica, and Guinea are all extremely rich in bauxite. Morocco has 7% of the total world phosphate rock resources, and Zambia 7% of total world copper resources. Zaire is also rich in copper and is the world's largest producer of cobalt, germanium, and industrial diamonds. While the other countries (Botswana, Liberia, Mauritania, Sierre Leone, and Togo) do not have significant mineral resources in terms of world mineral economy, their resources are definitely significant for their national economy.

As might be expected, the percentage of GDP which can be attributed to mineral production varies within this group. Generally, all these countries export a large amount (60-80%), if not the total amount, of the minerals they produce. Zambia, for example, exported 60% of its cobalt, 95% of its copper, 75% of its lead, and 60% of its zinc in 1974. While Zambia also exports some tobacco and maize, these products are not as significant as the minerals. In 1974 agriculture comprised slightly over 10% of Zambia's GDP, manufacturing 13%, and mining 40%. It is likely that mineral refining will make up a large part of these countries' manufacturing activity, although it will not be classified as manufacturing. This is true, for instance, with copper refining in Zambia.

The main Zambian cash crops are maize and tobacco, but the majority of the output comes from the larger commercial farms. In the past the commercial farms have been European, but African farmers have become more predominant particularly with new crops such as cotton, rice and poultry.

While the primary exporters do not have highly developed infrastructures compared to developed nations, there seems to be a definite realization that good transportation systems in particular are a necessity for both an export economy and a better-developed infrastructure. Liberia, for one, has developed the Robertsfield International Airport, and water and sewage systems, a road system and a new medical center in Monrovia. Zambia and Zaire have both paid increasing attention to their internal road networks (21,500 miles of roads are open in Zambia) and both also have international airports. A new Botswana-Zambia highway and Tanzania-Zambia railway handle about two-thirds of Zambia's exports. Zaire has recently developed national microwave communications, linking Kinshasa and Lubumbashi.

Although these countries on the whole are not large energy consumers, they still need imported energy since they still consume more energy than they produce. In fact, few of the countries produce any substantial amounts of energy; Zaire and Zambia are exceptions. Most of the energy produced is hydroelectric. Guinea, Jamaica, Liberia, and Morocco consume all the hydroelectric energy that they produce; Zaire almost meets its needs; Zambia produces more than it consumes. Also, Zambia's coal production is almost equal to its consumption; the same is true for Morocco.

Since most of these countries are without large supplies of energy, they must import most, if not all, of their petroleum needs. Botswana, Liberia, Guinea, and Togo are particularly dependent on imports. While Guyana and Togo have been involved in petroleum exploration, only Zaire and Morocco have discovered native petroleum deposits (Zaire also is exploring natural gas deposits in Lake Kivu). At least six of these countries (Zambia, Zaire, Togo, Sierra Leone, Liberia and Jamaica) have their own petroleum refineries.

Looking at this group as a whole, certain developmental trends and options, emerge that are generally applicable to these countries. They are:

- . continuing the present production of the most important mineral commodity or commodities; and in some cases, integrating forward into minerals processing in order to increase foreign exchange earnings per unit of mineral extracted;
- . investigating and developing other possible mineral resources;
- . investigating internal energy options;
- . upgrading roads and railroad systems;
- . developing new ports or increasing the efficiency of present ports;
- . increasing nationalization of the labor force, particularly in the mineral industry;
- . increasing training and education, both generally and specifically, for mining;
- . focusing more attention on the agricultural sector; and
- . beginning or cementing joint country ventures.

An example of integration into minerals processing is Morocco's development of phosphoric acid (P_2O_5) plants based on its extensive phosphorus reserves. This, together with similar development in Tunisia, has displaced much of Europe's P_2O_5 capacity.

Most of these countries also are interested in investigating and developing new minerals. Botswana, for example, has found gypsum, new copper sites

and kimberlite and will probably mine all three. Sierra Leone has prospected actively for chromite, cassiterite, platinum, columbite, gold, iron ore, rutile, and bauxite.

Another minerals related trend is this group's attempt to achieve some stability in commodity prices and therefore earnings. While Jamaica and others have attempted to form an OPEC-like bauxite cartel, the situation of the copper producers is the most noteworthy. Serious price declines in copper combined with high energy, food grain, and other prices have left Zaire, in particular, with a serious imbalance of international payments. Efforts at cartel pricing, international price stabilization agreements, or other arrangements have been unsuccessful to date.

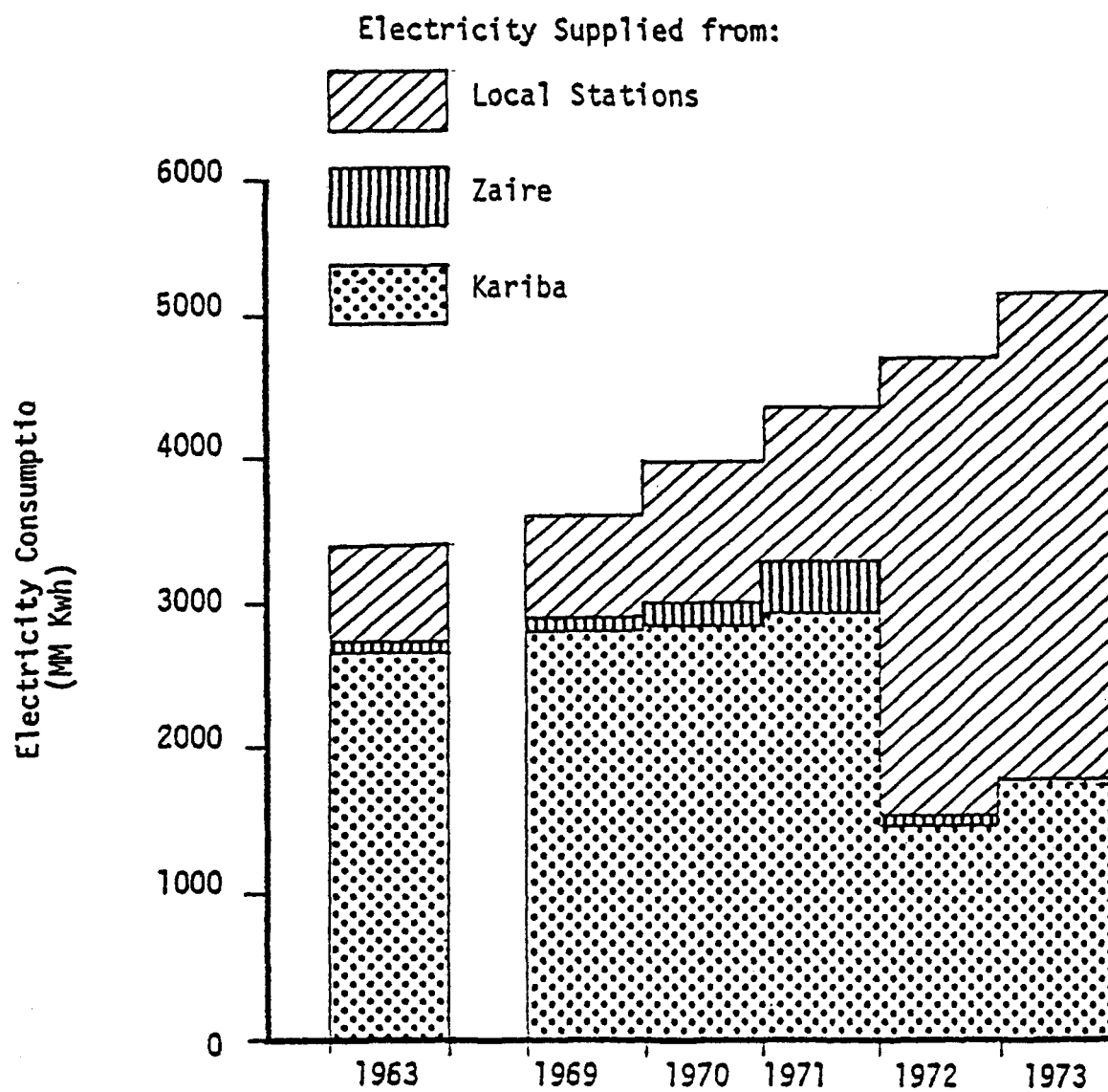
Several of the primary exporters are especially interested in exploring their energy potential. This is partly due to an unwillingness to be dependent on others for their needs and partly to an increased awareness of their countries' natural resources. For example, just ten years ago, Zambia was very dependent on foreign sources for coal and electricity. At present, coal imports have ended, and Exhibit 83 illustrates her diminished reliance on "outside" electricity. In addition, Zambia has continued to explore its wealth of resources. With its four major lakes and two major rivers, hydroelectric power is beginning to take an important place in Zambia's energy scheme. Besides the three major existing hydro developments, extensions and two new sites are anticipated. Her present sites produce 10,500 GWh of firm energy and with new sites the total is projected to be 27,000 GWh. Zambia is also exploring the possibility of increasing production and the use of charcoal for cooking, heating and distillation. Finally, it has several houses equipped to utilize solar energy for heating and a hospital under construction that will use solar energy to heat its water.

Again, improving this group's transportation infrastructure is an important priority, in fact, a necessity. In addition to inland transport and port facilities necessary to handle their exportable commodities, many countries in this group have yet to "grow" into their territory in terms either of integrating the tribes into a national entity or, in some cases, of even populating all habitable areas. For these countries, transport also is an important means of achieving national integration.

Efforts to increase the nationalization of the labor force go hand in hand with efforts for increased training and education. Especially in the mining industry, expatriates have higher, more well-paid positions than the Africans. Liberia has made concerted efforts with elementary and secondary schools, and Zambia and Zaire are also concerned with education problems; specifically, Zambia is interested in reducing the foreign labor force and must educate its own workers before this can happen.

In these countries it is often easy to ignore the agricultural sector -- particularly the subsistence sector -- since it does not contribute significantly to a country's economy. Although Liberia and Zambia have been placing

EXHIBIT 83. ELECTRICITY CONSUMPTION IN ZAMBIA



Source: EIU, Annual Supplement, p. 15.

high priority on agricultural development, discrepancies still exist. Because mineral production/exportation is a chief interest of this group, there is often a large split between the urban and agricultural areas. In Zambia towns and commercial agriculture have been built up around the railway line, but the very rural, subsistence agriculture in the Eastern and Western provinces has been ignored. Although Zambia's growth rate is 2.9%, the urban growth rate is 6%, thus indicating a low rural growth rate. At the same time, the subsistence agriculture sector makes up roughly 50% of the labor force. Agricultural loans in Zambia were up 20% over 1976, reflecting some diversion of resources to this sector.

For the African nations of this group, one trend is to continue or to initiate joint country ventures. Some of these ventures are already working: for example, the Tanzania-Zambia Railroad which aids both Zambia and Zaire, and the Botswana-Zambia highway which may eventually extend through to Malawi. Their anticipated new ventures include a hydroelectric development on the Luapula River to be shared by Zaire and Zambia. One of the main problems of joint country ventures is the "political aspect," as the internal political workings of one country can greatly affect another. Angola, for example, was once the major country through which Zaire and Zambia routed their exports. But, with the outbreak of civil war in Angola, all such movement was stopped. When Zaire's and Zambia's rolling stock was held by Angola, a new route had to be found and developed (through Tanzania), and exporting was greatly hampered.

With regard to their energy policy options, the situation of the exporters of primary products is in some respects similar to that of the industrialized LDCs: they are limited in their ability to institute intersectoral shifts in economic activity by the fact that a single sector mining provides their principal resource for economic development. The equipment used in mining is energy intensive, and is based on imported technologies. The exploitation and distribution of mineral resources also requires highly developed transportation networks to bring minerals, in volume, to ports. Unlike industrialized LDCs, however, the sector to which these countries are committed is not capable of expanding to the point of employing a significant share of the labor force. In fact, the development strategies of primary exporters usually involve an attempt at economic diversification. Insofar as they are not yet committed to any specific form of diversification, they are more capable of reordering their economic priorities, outside the mining sector, in response to energy bottlenecks.

5.4 AGRICULTURALLY ORIENTED ECONOMIES

The agriculturally oriented LDCs form a belt up the east coast of Africa and across the continent to the tropical countries of West Africa; they also comprise most of the Central American nations, and are spotted across Asia and South America. They experience the lowest per capita GNP, the least urbanization, the lowest life expectancy, and the smallest per capita consumption of commercial energy of all the country groups.

The group has a mean life expectancy of 47.6 and includes the lowest figure for any country in the world. In the central African nation of Chad the life expectancy for males is 29 years. Men and women in five agrarian

African economies have average expected life spans of less than 40 years. Only in a few island nations and those in the Americas does this average climb to above sixty. Infant mortality and the overall crude death rate span a similar range. The central African and Asian nations experience infant mortality rates of between 150-200 deaths per 1000 births, compared to less than 100 per 1000 in the Americas. Death rates are in the mid 20s per 1000 in most of the African and Asian countries, but range around 10 for the island nations and in the Americas.

Although dismal, these statistics reflect a favorable trend. Infant mortality is half that of the early years of this century. Life expectancy is half again what it was, and the crude death rate has been dropping steadily. This has resulted in a 2.4% mean annual rate of population growth for the group. The population of these agrarian nations will double in 29 years.

These nations' land is characterized by tropical woodlands and grasslands, equatorial forests, areas with deciduous or coniferous forests, grazing land including marginal farm land, and arable soils suited to intensive farming. Most of the area is under shifting or marginal cultivation; hunting, gathering and primitive cultivation are also prevalent. Nomadic herding is practiced within several of the northern African nations, and plantation crops are cultivated in dispersed pockets usually located in coastal areas. These countries are uniformly without significant commercial quantities of mineral resources.

The traditional sector comprises over 70% of the population of these economies; in some African nations such as Swaziland and Rwanda, over 90% of the population is employed by the traditional sector (Exhibit 84). This primary segment of the population engages in non-monetary subsistence farming. Of the economically active population, 91% is in agriculture in Rwanda, 81% in Ethiopia, and 79% in Afghanistan. This percentage ranges above 75% for nearly all members of this group.

Land use is determined by tradition and cultivation techniques are often primitive, resulting in a skewed seasonal demand for labor. Although they are essential for the development of arable land, irrigation and fertilizers have limited use. Only the agricultural exporters use a significant amount of modern techniques, but their use is limited and affects only a small portion of the population.

The modern sector is small and is controlled by an even smaller proportion of the population. In the main it consists of a weak, geographically limited industrial infrastructure superimposed on the traditional economy. This sector is the medium for economic transactions with the rest of the world and hence is more developed in the agricultural exporting countries.

The bulk of energy consumption in these societies is of noncommercial fuels, primarily wood with some crop residues and animal wastes. Well over half of the population relies upon such fuels for their entire energy needs beyond foodstuffs. Lacking an infrastructure that provides a base for the distribution of commercial energy supplies, the rural populations are dependent upon these fuels, wood in particular. Wood fuels used for cooking range from 50% of the

EXHIBIT 84. STRUCTURE OF POPULATION, AGRICULTURALLY ORIENTED ECONOMIES

	<u>Population</u>		<u>Economically Active Population</u>		
	<u>Total</u>	<u>Agricultural</u>	<u>Total</u>	<u>Agriculture</u>	<u>Agriculture(%)</u>
Afghanistan	19796	15725	6728	5344	79.4
Bangladesh	75529	64106	25933	22011	84.9
Benin	3160	1500	1487	706	47.5
Burma	31992	17523	13107	7179	54.8
Burundi	3863	3274	1858	1608	84.7
Cameroon	6571	5409	3127	2574	82.3
Gen. African Empire	1829	1628	1002	692	69.0
Chad	4016	3476	1551	1342	86.6
Comoros	314	204	116	76	65.0
Costa Rica	2014	764	655	249	37.9
Cyprus	681	244	295	106	35.8
Dominican Republic	5291	3079	1399	814	58.2
El Salvador	4239	2288	1316	694	52.7
Equatorial Guinea	319	245	96	73	76.9
Ethiopia	28854	23443	12128	9862	81.2
Fiji	589	253	187	80	43.0
Gambia	520	414	250	207	79.6
Ghana	10161	5513	3798	2042	52.8
Guatemala	6312	3619	1930	1106	57.3
Haiti	4626	3227	2361	1647	69.8
Honduras	3143	2017	931	597	64.2
Jordan	2779	804	679	194	28.9
Ivory Coast	5014	4088	2571	2096	81.5
Kenya	13701	10890	5329	4235	79.5
Lebanon	2959	399	768	104	13.5
Lesotho	1173	1013	630	544	86.4
Madagascar	8263	7101	4114	3536	85.9
Malawi	5035	4332	2291	1972	86.0
Mali	5342	5183	3198	2838	88.7
Mauritius	914	278	310	94	30.4
Mozambique	9461	6453	3697	2522	68.2
Nepal	12877	11988	6199	5771	93.1
Nicaragua	2396	1085	714	330	46.3
Niger	4732	4252	1486	1338	90.1
Papua New Guinea	2783	2333	1410	1182	83.8
Paraguay	2724	1373	872	439	50.4
Rwanda	4362	3976	2315	2110	91.1
Senegal	4526	3465	1923	1472	76.6
Somalia	3258	2670	1235	1054	82.0
Sri Lanka	14252	7727	4869	2635	54.1
Sudan	18850	14889	5922	4678	79.0
Surinam	434	85	108	21	19.6
Swaziland	483	369	225	172	76.3
Tanzania	15872	13191	6637	5516	83.1
Thailand	43490	33590	19765	15256	77.2
Uganda	11701	9714	4509	4075	83.0
Upper Volta	6173	5170	3334	2792	83.8
Yemen Arab Republic	6268	5271	1931	1482	76.7

Source: 1976 FAO Production Yearbook, Vol. 300, (Food and Agriculture Organization of the United Nations, Rome, 1977), pp. 96-72.

total wood fuel consumption in cold climates to 90% in warmer areas. Commercial energy use for selected agriculturally oriented economies is depicted in Exhibit 85.

The agricultural economies are homogenous with respect to their inability to finance their projected energy needs, due to: the scarcity of easily accessible energy resources, the lack of a modern economic infrastructure, and the absence of exportable primary resources. Development strategies based on the creation of a modern sector and its attendant infrastructure may therefore be subject to reconsideration. Emphasis will turn to less energy intensive development paths that maximize the social rate of return on scarce capital.

Strategies that aim to employ the two abundant resources of these countries, land and labor, probably represent the most productive ways of utilizing scarce capital. Given the overwhelming preponderance of the agricultural sector, an increase in its productivity will make a significant difference. Traditional studies have consistently underestimated the magnitude of the possible effect of a successful mobilization of idle manpower. This failure of appreciation has been mainly due to the assumptions about the shape which development programs should take. It has been implicitly assumed that development would, in the main, have to take the form of industrial growth absorbing the unemployed and underemployed of the rural areas.

The agriculturally oriented economies are likely to face more severe financial problems regarding their energy than any LDC group. Their development prospects are heavily dependent on the flow of bilateral and multilateral public assistance. There is a pronounced need to meet basic development goals by new means, a preception which has already begun to shape the approaches of international agencies such as the World Bank, and is therefore likely to be reflected in the programs of these aid-dependent nations.

Because of their narrow resource base, the countries in this group have a limited range of solutions to energy scarcity, and have suffered grave economic consequences during the energy crisis. Their most viable options are likely to lie in the attempt to increase their agricultural productivity through land and labor intensive techniques. Response to their energy needs will depend upon the application of such small-scale technologies as solar, biomass, biogas, etc., and through environmental policies that protect and enhance their available renewable energy resources, such as reforestation and fuelwood plantations. Tapping their potentially vast renewable energy sources could do more than simply reduce their dependence on imported fuels. The technologies, once implanted, are consistent with improvements in rural lifestyles and productivity:

- . the electricity from biogas units would allow improved education, recreation and communications,
- . cooking gas (from biogasification) or solar cooling devices would reduce the time spent in gathering fuelwood (already up to several hours per day in many LDCs), while simultaneously alleviating pressure, and

EXHIBIT 85. SELECTED AGRICULTURALLY ORIENTED ECONOMIES' 1975 PRODUCTION AND CONSUMPTION OF COMMERCIAL ENERGY
(In Million Metric Tons - Coal Equivalent)

Country	Total			Coal & Ignite/Solid Fuels			Crude Liquid Gas/Liquid Fuels			Natural Gas			Hydroelectric - Nuclear		
	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C
Afghanistan	4.236	1.011	4.18	.109	.109	1.00	.010	.684	.02	3.947	.140	26.66	.090	.090	1.00
Bangladesh	.693	2.179	.31	-	.340	0	-	1.146	0	.631	.631	1.00	.061	.061	1.00
Cameroon	.140	.660	.20	-	.001	0	-	.627	0	-	-	NA	.140	.140	1.00
Con. African Emp.	.006	.061	.09	-	-	NA	-	.055	0	-	-	NA	.006	.006	1.00
Chad	-	.158	0	-	-	NA	-	.158	0	-	-	NA	-	-	NA
Costa Rica	.161	1.070	.15	-	-	NA	-	.909	0	-	-	NA	.161	.161	1.00
El Salvador	.069	.993	.06	-	-	NA	-	.924	0	-	-	NA	.069	.069	1.00
Ethiopia	.043	.880	.05	-	.003	0	-	.754	0	-	-	NA	.043	.043	1.00
Ivory Coast	.034	1.787	.02	-	-	NA	-	1.753	0	-	-	NA	.034	.034	1.00
Kenya	.031	.285	.10	-	.060	0	-	.194	0	-	-	NA	.031	.031	1.00
Nicaragua	.048	1.033	.04	-	-	NA	-	.905	0	-	-	NA	.048	.048	1.00
Niger	-	.163	0	-	-	NA	-	.163	0	-	-	NA	-	-	NA
Pap. New Guinea	.022	.766	.03	-	-	NA	-	.743	0	-	-	NA	.022	.022	1.00
Senegal	-	.807	0	-	-	NA	-	.007	0	-	-	NA	-	-	NA
Sudan	.015	2.479	.01	-	-	NA	-	2.464	0	-	-	NA	.015	.015	1.00
Tanzania	.042	1.026	.04	.001	.002	.50	-	.903	0	-	-	NA	.041	.041	1.00
Thailand	.458	11.897	.03	.136	.162	.03	.009	11.400	*	-	-	NA	.314	.335	.93

* Less than .001

Source: UN, World Energy Supplies 1971-1975, 1977.

irrigation systems relying on renewable sources can contribute to agricultural productivity, as can locally produced fertilizers.

Finally, although the percentage of population in the modern sector is small, it consumes a sizable portion of these countries' imported energy. Limiting this consumption can significantly reduce the drain on their scarce foreign exchange reserves.

5.5 OIL EXPORTING LDCs

It is obvious that energy shortage impacts take an altogether different dimension in the oil exporting LDCs. While other countries respond to energy scarcity by attempting to reduce demand, the primary response of these countries occurs on the supply side. However, as energy prices rise and their incentive for further production increases, their incentive to conserve energy will also rise due to the thrust of lost revenues.

The development strategies of this group are oriented towards the following objectives:

- . expanding supply to take advantage of price increases,
- . transforming current revenue flows into a diversified economic base for long-run growth,
- . using as much energy as is necessary for the development of a diversified economic base, and
- . encouraging energy conservation insofar as it is consistent with the above objectives, both in order to avoid long-term shortages and in order to maximize current revenue-generating exports.

As discussed in the earlier energy supply sections, the group is expected to broaden over the next few years as LDCs receive relatively more exploration emphasis. Potential short-run examples include Argentina, Guatemala (presuming, as is expected, that the Reforma field extends southward into that country), and possibly the coastal countries of French West Africa (e.g. Ivory Coast).

The two major, related decisions facing each country with potentially exportable oil resources are: (1) the rate of development and use of such resources, and (2) the rate and pattern of use of the public (and, to the extent controllable, private) savings represented by the excess of government and company revenues over costs. The first decision relates to both the rate of depletion of reserves and the allocation to domestic uses versus export (the latter implying a greater degree of domestic energy conservation or use of other energy sources). The second relates particularly to the country's overall financial position (which, in most present non-OPEC oil exporting countries, is not strong).

Because most of the present non-OPEC oil exporting countries (Oman being the notable exception) face sizable short-term debt service and/or domestic public spending needs, they are likely as a group to press for higher production and exports than does OPEC as a group. Longer-term, their interests are more likely to coincide with those of OPEC. Finally, because it is not adversely affected, this group must be considered as the one least likely to conserve energy or to alter the strategies (except, insofar as their more favorable investment position merits the development of other indigenous energy supplies) discussed in Section 4.1.

Responses of LDC energy exporting countries will vary according to their energy development, history, current political attitudes, and their level of access to modern petroleum development technology. The responses of Mexico, Angola, and Egypt are representative of this group, and are discussed below.

5.5.1 Mexico

Mexican oil production during the first nine months of 1977 was 20.4% higher than in 1976. As production climbed steadily above the one-million-barrel-per-day mark, the Mexican government was continually forced to raise its estimates of oil and gas reserves. In November Mexico's proven oil reserves were estimated to be 16.8 billion barrels as opposed to 11.2 billion barrels in December 1976. Official estimates of probable reserves were 29.2 billion barrels, although knowledgeable unofficial observers insisted that the figure should have been closer to 60 billion barrels. Average daily oil production for all of 1977 is expected to reach 1.1 million barrels, 10% above the target level.

As of November 1977, some 60 structures with commercial oil potential had been identified in the Reforma Area. Although 120 promising structures have been discovered, only four structures had been brought into production, all offshore in the Reforma Area. Each of the four wells that were drilled in three structures produced over 5,000 BPD.

. Mexican Oil and Gas Development Policy

- Mexico's new Lopez Portillo administration, inaugurated December 1, 1976, reversed the conservationist policies of the previous administration and announced a new program for the development of Mexican oil production, including a 50% increase in the PEMEX (national oil company) budget to 15.5 billion dollars, and a 6-year investment program. This program sets the 1982 oil production goal at 2.3 million barrels a day, 1.1 million barrels of which would be exported.
- The PEMEX 6-year energy expansion program included plans to expand natural gas production to 4 billion cubic feet per day in 1982, from an average of 2.1 billion cubic feet per day in 1976.

- The \$15.5 billion investment program includes \$7.13 billion for drilling and production and \$1.24 billion for exploration. The other 46% of the investment is marked for refining, petrochemicals, and transportation.
- PEMEX plans include 1,324 exploration and 2,152 development wells through 1982, or approximately twice as many wells as were drilled in 1976.
- PEMEX plans to explore 25 of the most promising structures in its Reforma fields thoroughly, and then put two production platforms on five of the best of these, each platform with 12 wells.
- During the last four years of exploratory drilling, PEMEX has maintained an 82% success ratio.

Export Marketing Policy

- Mexico's oil export expansion may either continue to be accomplished through international oil companies, or through government-to-government crude sales. Although Mexico is not a member of OPEC, its oil marketing program may include cooperation with other oil-producing governments.
- Some 15% of the 1.1 million barrels a day 1982 export goal would be in the form of products. This will require the expansion of many of Mexico's older refineries and the building of new ones to accommodate Mexico's domestic demand (.85 million barrels per day in 1977) and its crude exports (.2 million barrels per day).
- PEMEX has announced plans to build an 800 mile, 48-inch pipeline to carry natural gas from the Reforma fields (where the gas is currently being flared) to Northern Mexico and the United States. PEMEX has signed agreements with several U.S. gas pipeline companies for purchase of the gas.

. Policy Toward Other Energy

- Mexico's Council on Mineral Resources is directing a national program to expand coal production, much of which is used for electricity generation. Mexico has contracted with a Polish company (Kopex), to develop a part of the Coahuila coal deposits at Rio Escondido.
- Mexico's Federal Electricity Commission provides 90% of Mexico's electricity (46 billion kilowatts demand in 1976). The other 10% is generated by some 2300 plants with private or mixed private and public ownership.

5.5.2 Angola

Although civil strife has continued to hamper exploratory efforts and the expansion of oil reserves in Angola, oil production continued to increase gradually as the new Angolan government pondered decisions on how to handle the foreign oil companies which discovered and continued to produce Angolan oil in late 1977. Drilling decreased sharply from 20 wells drilled in 1975 to 5 wells in 1976. Whereas 5 of the 20 wells drilled in 1975 were dry, all 5 drilled in 1976 were completed for oil. Angola's proved oil reserves are estimated to have slipped during 1976 by about 37 million barrels to 1.32 billion and to 1.16 billion in 1977, while gas reserves were depleted by about 300 billion cubic feet to 1.48 trillion cubic feet.

. Angolan Oil and Gas Development Policy

- The Angolan government has indicated that it wants a larger share than its present 55% equity participation in Gulf Oil Company's production. Meanwhile, Texaco and Petrofina have received permission to retain their entire production profits in hard currency without repatriating them to Angola. The only production company fully nationalized in 1977 was the Portuguese company Angol, in keeping with Angola's policy of nationalizing all former Portuguese interests.
- The government plans to establish a new national oil company to supervise all of its production and distribution in Angola; and has sought the advice of Algeria's national energy company, Sonatrach. Algeria was one of the first oil producing former LDCs to assume operating control over its oil and gas reserves. (Although Sonatrach has achieved 100% control of its petroleum exploration, refining, and marketing operations, as of late 1977 its share of crude oil production in Algeria was still only 80%. Sonatrach has hired a number of foreign and petroleum service companies to assist in production operations, and employs a mixture of its own technicians and former oil company expatriate technicians to maintain existing production.) Sonatrach has offered to train Angolan technicians on Algerian installations, and has also offered Angola financial assistance in developing its oil and gas industry.
- Realizing that domestic capital is insufficient to support the magnitude of energy development which the government hopes for, its new constitution provides some guarantees for the interests of international corporations if they agree to help in the development of the country.

. Policy Toward Other Energy

- Associated gas (produced with the crude oil) fuels a 2,000 kilowatt power station at the Cabinda terminal. Another 2 million cubic feet of associated gas per day is supplied to a state-owned, 4500 kilowatt electric power plant which previously burned diesel fuel to provide electric power for Cabinda Town.
- By late 1977 Angola had completed 3 smaller dams in a 13-dam hydropower project on the Cunene River with an estimated total electricity producing potential of about 1700 megawatts. Financed by a combination of Portuguese, South African, French and Belgian interests, this project has been delayed both by the civil fighting and the continuing absence of an electricity distribution grid.

5.5.3 Egypt

Although petroleum development is Egypt's most important future energy goal, her main source of energy for many years has been hydropower. Oil production of 450,000 barrels per day during 1977 exceeded the Egyptian government's 1977 production goal of 400,000 bbls per day and exceeded 1976 production by 28%. Egypt's hopes of becoming an important crude oil exporter have improved markedly. Her crude oil production target for 1980 is one million barrels per day. Any agreement reached with Israel will represent increased stability to potential investors, and should provide a significant boost in oil and gas investment by foreign companies in Egypt.

. Egyptian Oil and Gas Development Policy

- In 1971 Egyptian President Anwar Sadat began to reverse the foreign investment policies of his predecessor. President Nasser, in order to make the Egyptian economy attractive once more to commercial investment by western companies rather than by socialist countries. This change in foreign investment policy was designed to stimulate petroleum export revenues and attract foreign companies' energy capital and technology to develop Egypt's oil and gas resources.
- The Egyptian government concluded some 30 production sharing exploration contracts with foreign oil companies; making Egypt the most active exploration area in Africa in 1977.
- Egypt offered the companies the following commercial terms: the companies are required to spend a specified investment signature bonus of several million dollars, and promise a certain amount of exploration investment over a period of time. If the company discovers oil, it is granted 20-50% of total commercial production to repay its investment, and access to crude for export.

- Egypt has received over \$100 million in revenues from contract signature bonuses; companies invested some \$700 million in exploration between May 1973 and the end of 1977. In 1977 they spent an estimated \$360 million in exploration and development while the Egyptian government's 1977 budget for the Egyptian Petroleum Corporation was some \$2.2 billion.
- In late 1977 foreign oil companies announced plans to spend \$893 million, and the Egyptian government budgeted \$365 million on Egyptian oil exploration and development operations for 1978.

EXHIBIT 86. CURRENT OIL EXPORTERS' 1975 PRODUCTION AND CONSUMPTION OF COMMERCIAL ENERGY
(In Million Metric Tons - Coal Equivalent)

Country	Total			Coal & Ignite/Solid Fuels			Crude Liquid Gas/Liquid Fuels			Natural Gas			Hydroelectric - Nuclear		
	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C	Production	Consumption	P/C
Angola	11.917	1.113	10.7	-	-	NA	11.800	.996	11.8	-	-	NA	.117	.117	1.00
Bolivia	4.949	1.707	2.9	-	-	NA	2.766	1.374	2.0	2.007	.238	8.80	.095	.095	1.00
Brunei	21.290	1.415	15.0	-	-	NA	12.793	.116	110.3	8.505	1.300	6.60	-	-	NA
Congo	2.660	.201	9.5	-	-	NA	2.630	.251	10.6	.023	.023	1.00	.007	.007	1.00
Egypt	13.299	15.092	.88	-	1.538	0	12.309	12.645	.97	.073	.073	1.00	.836	.836	1.00
Malaysia	7.008	6.661	1.052	-	.052	-	6.884	6.287	1.095	-	0.2	-	0.124	0.124	-
Mexico	84.436	73.431	1.2	5.128	5.708	.89	59.022	47.075	1.2	18.363	18.691	.98	1.923	1.957	.98
Oman	25.014	.259	96.6	-	-	NA	25.014	.259	96.6	-	-	NA	-	-	NA
Syrian Arab Rep.	14.359	3.505	4.1	-	.003	0	14.071	3.214	4.4	.279	.279	1.00	.009	.009	1.00
Trinidad Tobago	18.251	3.373	5.4	-	-	NA	16.496	1.618	10.2	1.756	1.756	1.00	-	-	NA
Tunisia	7.111	2.579	2.7	-	.131	0	6.775	2.112	3.2	.332	.332	1.00	.004	.004	1.00

Source: UN, World Energy Supplies 1971-1975, 1977.

APPENDIX A. LDC ENERGY CONSUMPTION ASSUMPTIONS AND METHODOLOGIES

Appendix A describes the methodology used to calculate LDC energy consumption and contains information from various sources considered in the determination of the growth rates and elasticities utilized in this study.

Methodology:

Countries were classified by the categories developed by Gordian Associates, described in the Executive Summary and Chapter 5.

Computation of the 1975 energy consumption data base by energy source was derived from the United Nations' publication World Energy Supplies, 1971-1975 as follows:

Oil consumption -- Table 10, "Trade and Apparent Consumption of Energy Petroleum Products" (units in million metric tons).

Natural Gas consumption -- Table 15, "Production, Trade and Apparent Consumption of Natural Gas" (units in thousand teracalories).

Coal consumption -- Table 3, "Production, Trade and Consumption of Solid Fuels" (units in million metric tons of coal equivalent).

ALTERNATIVE ASSUMPTION

The following tables summarize relevant assumptions from other reports.

A. Average Annual LDC Population Growth Rates (%/yr)

<u>WAES¹</u>	<u>1970-75</u>	<u>1976-85</u>	<u>1986-2000</u>
Low Income LDCs	2.5	2.65	2.3
S. Asia	2.4	2.6	2.2
Africa	2.7	2.9	2.9
Middle Income LDCs	2.7	2.75	2.5
E. Asia	2.8	2.7	2.3
Africa	2.6	2.7	2.6
W. Hemisphere	2.8	2.6	2.6
Total non-OPEC LDCs	2.6	2.7	2.4
Total WOCA	2.1	2.2	2.05
<u>Leontief/UN (all LDCs)²</u>			<u>1970-2000</u>
Scenario X			2.3%
Scenario C			2.0%
Scenario A			2.3%
<u>Strout³</u>			<u>1973-2000</u>
All non-OPEC LDCs			2.4%

B. Average Annual Growth in GNP/GDP Per Capita (%/yr)

<u>WAES¹</u>	<u>1976-85</u>		<u>1985-2000</u>	
	<u>High</u>	<u>Low</u>	<u>High</u>	<u>Low</u>
Low Income	1.7	0.15	0.8	0.2
Middle Income	3.7	1.7	2.3	1.4
Total non-OPEC LDCs	3.3	1.4	2.1	1.2
Total WOCA	2.9	1.2	1.9	0.7
<u>Leontief (All LDCs)²</u>				<u>1970-2000</u>
Scenario X			4.9	
Scenario C			4.9	
Scenario A			3.1	
<u>Strout³</u>				<u>1973-2000</u>
All Non-OPEC LDCs			2.9	

C. Average Annual GNP Growth (%/yr.)

<u>WAES¹</u>	<u>1976-1985</u>		<u>1985-2000</u>	
	<u>High</u>	<u>Low</u>	<u>High</u>	<u>Low</u>
Low Income	4.4	2.8	3.1	2.5
Middle Income	6.6	4.5	4.9	3.9
Total non-OPEC LDCs	6.1	4.1	4.6	3.6
Total WOCA	5.2	3.4	4.0	2.8

Leontief²1970-2000

Scenario X Regional LDC Growth Rates

Latin American Middle Income	7.1%
Latin America Low-Income	7.2%
Middle East (incl. OPEC)	9.0%
Asia	6.7%
Africa - Arid	5.5%
Africa - Tropical	6.5%
Developing Centrally Planned	6.3%
Total Developing Countries	7.2%
Scenario C (Total Developing Countries)	6.9%
Scenario A (Total Developing Countries)	5.4%

OECD World Energy Outlook 1977⁴

	<u>1971-73</u>	<u>1974-76</u>	<u>1977-80</u>	<u>1982-85</u>
Major Oil Exporters	7.8	8.9	6.2	8.0
Other Developing Countries	5.9	4.5	5.6	6.1

Lambertini⁵1974-80

Middle and High Income LDCs	5.5
Low Income LDCs	4.5

World Bank Staff Estimates⁶1976-801981-85

Upper Middle Income LDCs	4.73	5.88
Lower Middle Income LDCs	7.07	6.35
Intermediate Income LDCs	6.10	7.48
Low Income LDCs	4.08	4.31
Capital Deficit Oil Exporters	7.57	6.90
Total Developing Countries	5.98	6.57
Total Excluding Capital Deficit Oil Exporters	5.58	6.49

Strout³1973-2000

All Non-OPEC LDCs	5.39
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World Energy Conference 1977⁷

	<u>1975-2020</u>	
	<u>High</u>	<u>Low</u>
Worldwide GNP Growth	4.2	3.0

D. Income Elasticity of Demand For Energy

	<u>1960-72</u>	<u>1976-85</u>	<u>1985-2000</u>	<u>1985-2000</u>
<u>WAES</u> ⁸ Oil Price (1975 US \$):	<u>\$2.00</u>	<u>\$11.50</u>	<u>\$11.50</u>	<u>\$11.50/\$17.25</u>
Low Income LDCs	1.62	1.50	1.20	1.30
Middle Income LDCs	1.24	1.10	1.00	1.05
Total Non-OPEC LDCs	1.29	1.19	1.04	1.10

(see footnote 8 for regional breakdown of 1960-72 "elasticities")

Leontief (Scenario X)⁹

	<u>1970-2000</u>
Petroleum	1.26
Natural Gas	1.44
Coal	0.89

(all developing countries, including OPEC)

OECD World Energy Outlook 1977¹⁰

(Non-OPEC LDCs)	<u>1974-1980</u>	<u>1981-85</u>
Solid Fuels	1.28	0.32
Oil and NGL	0.18	0.49
Gas	2.15	1.50
Primary Electricity	2.58	2.28
Total Primary Commercial Energy	0.95	0.96

Lambertini (1974-80)¹¹

	<u>High Income</u>	<u>Middle Income</u>	<u>Lower Income</u>
Coal	*	*	*
Oil	0.88	1.1	0.85
Natural Gas	1	*	*
Electricity	1.15	1.6	1.8

(*: See footnote 11)

World Bank staff estimates⁶

(Oil Importing LDCs Only)	<u>1976-80</u>	<u>1981-85</u>
Total Commercial Primary Energy	1.08	0.77
Primary Electricity	1.73	1.33

Strout³1973-2000

All Non-OPEC LDCs

1.2

World Energy Conference 1977^{12/}1975-2020High GNP GrowthLow GNP GrowthWorld primary Energy (incl.
Wood Fuel)

1.07

1.05

Price Elasticity of Demand For EnergyWorld Energy Conference 1977^{12/}1975-2020High GNP GrowthLow GNP Growth

"Medium Price Response"

-.156

-.162

"High Price Response"

-.205

-.211

WAES (1985 only)¹³High GNP GrowthLow GNP GrowthNon-OECDTotal WOCANon-OECDTotal WOCA

Coal

-.105

-.160

-.181

-.488

Oil

-.139

-.126

-.270

-.299

Gas

-.077

-.032

-.102

+.029

Total Fossil Fuels

-.108

-.094

-.199

-.211

Hydro

0

0

0

+.136

Nuclear

0

0

0

+.090

Other

0

0

0

+1.19

Total Primary Energy

-0096

-0081

-.178

-.165

Lambertini¹¹High
IncomeMiddle
IncomeLower
Income

Oil

-.060

-.109

-.05

E. Projected Electric Power Plant Capacity
World Bank Staff Estimates

	<u>GWE</u> <u>1976</u>	<u>%</u>	<u>GWE</u> <u>1980</u>	<u>%</u>	<u>GWE</u> <u>1985</u>	<u>%</u>
Hydro	60.1	(48.0)	93.7	(47)	142.8	(47)
Nuclear	1.1	(1)	5.4	(3)	16.5	(5)
Thermal	65.0	(52)	101.0	(80)	143.9	(47)
Total	126.2	(100)	200.1	(100)	303.1	(100)

FOOTNOTES TO APPENDIX A

- 1 Workshop on Alternative Energy Strategies (WAES), Energy Supply-Demand Integrations to the Year 2000. "Low income" countries have annual per capita incomes under \$200 (1972\$), "middle income" countries have annual per capita incomes over \$200. "WOCA" means the "world outside Communist areas." Most of the figures are derived from UN population projections.
- 2 Wassily Leontief et. al., The Future of the World Economy -- A United Nations Study. Scenarios X and C assume a growth rate of LDC (including OPEC) gross product per capita "which will roughly halve the income gap between the developing and the developed countries, with a view towards closing the income gap completely by the middle of the next century." Growth rates of population are based on the "medium" (Scenario X) and "low" (Scenario C) projections made by the Population Division of the United Nations Secretariat. In Scenario A--referred to as the "old economic order" Scenario--population growth rates equal to those of Scenario X are assumed, and gross product growth rates are then determined endogenously in the model for all regions except the Middle East.
- 3 Alan M. Strout, The Future Of Nuclear Power in the Developing Countries.
- 4 OECD World Energy Outlook 1977. "Major oil exporters" include OPEC countries plus Bahrain, Oman, Brunei and Trinidad and Tobago.
- 5 Adrian Lambertini, Energy and Petroleum in non-OPEC Developing Countries 1974-1980, World Bank Staff Working Paper No. 229, Feb. 1976.
- 6 Gordian interviews with Enzo Grilli and B.J. Choe, October 1977. Growth rates and elasticity were derived from projected GNP levels in constant 1975 US dollars and projected energy consumption levels. Total developing countries include capital deficit oil exporters; categories other than "capital deficit oil exporters" exclude oil exporters.
- 7 World Energy Conference 1977, Conservation Commission, "Report on World Energy Demand, 1985-2000," Executive Summary, August 1977.
- 8 Income elasticity of demand for total commercial energy. See Energy Supply Demand Integration to the Year 2000, p. 222. No equation on calculation methods is given. However, calculations using Table 6.6 (p. 222 reproduced as Exhibit A-1 suggest that the WAES' "income elasticity" relationships are simply the energy growth rate divided by the GNP growth rate, with no attempt to account for effects of energy prices on other variables.
- 9 Derived from Leontief et. al., The Future of the World Economy, projections of energy resource consumption (Table 28, p. 46) and GNP. "Income elasticity" is simply energy consumption growth rate divided by GNP growth rate (the Leontief study does not explicitly address price effects).

- 10 Growth in total energy divided by growth in Gross Domestic Product (see p. 83). The derived 1974-1980 "income elasticities" appear to include substantial own-price and cross-price elasticity effects. Similarly, the low 1981-85 income elasticities for solid fuels and oil and NGLs appear to include lagged price elasticity effects.
- 11 Based on Annex LL. Coal consumption assumed equal to supply, middle and low-income LDC gas consumption based on countries' known expansion plans. Electricity consumption elasticities were derived by regressing current elasticity generation (kWh) on current income per capita (equation not included in Lambertini text). Oil consumption derived by combined cross-section/time series analysis yielding current oil consumption as a function of current-period GNP, current oil price, and the prior periods' consumption (see Lambertini text for equations).
- 12 Consumption response to doubling of real energy prices, from Exhibit 2 of Executive Summary, relative to "no price response" case.
- 13 Derived from "Energy Supply-Demand Integration to the Year 2000," Table 4.1, by comparing high and low growth cases at two real energy price levels (\$11.50 and \$17.25 in constant 1975 US dollars). Two low growth cases aren't strictly comparable because high-price case assumes "vigorous" national policy response (the reason for apparently positive price elasticities for certain energy types).