Energy Options and Policy Issues in Developing Countries

SWP-350

World Bank Staff Working Paper No. 350

August 1979

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A Background Study for World Development Report 1979

This paper reviews the energy resources of developing countries, with particular emphasis on those which import oil. It discusses the nature of these resources, the cost of developing them and the policy issues raised in doing so. The need for and implementation of national energy planning, energy demand management, conservation and pricing policy are described. Energy development strategies for countries in energy surplus, energy balance and energy deficit are discussed, as are problems related to petroleum refining and energy use in the transport sector. Issues related to power generation and fuel substitution and the relevant costs are reviewed.

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ENERGY OPTIONS AND POLICY ISSUES IN DEVELOPING COUNTRIES

Summary

The economic position of developing countries that are not oil exporters is steadily deteriorating with the continual rise in the price of oil and refined products, which constitute the main, and in many cases the only, energy supply for the developed part of their economies.

There are equally severe, but less well known, problems in the sector of traditional fuels, where deforestation and soil erosion are the main indicators because reliable statistical evidence is lacking.

Most developing countries have some kind of indigenous energy resource which could be developed to help ease the strain of petroleum imports but, with a few notable exceptions, little is being done to develop these resources.

Energy is vital to the development process and is essential even at the subsistence level; therefore, energy policy has a critical effect on national development. Despite this, few countries have a conscious energy policy, and energy planning is a relatively new discipline. More resources, both national and international, need to be devoted to these matters.

Energy planning requires an adequate basis of information on energy demand, consumption patterns, an inventory of national energy resources, and forecasts of supply and demand. Energy planning also requires an institutional structure which will permit planning recommendations to be made directly to the top levels of government and constant contact by the planning staff with other government institutions, since energy considerations enter into most aspects of national life.

Most of the energy resources proposed as substitutes for imported oil, such as coal, hydropower, and natural gas, in effect replace only heavy fuel oil. At present there is no available substitute for automotive fuels: gasoline and diesel fuel. While it is technically feasible to use ethyl alcohol as a substitute, doing so might entail diverting land away from food production; the economics of the production process, and its environmental aspects, require serious study.

Many developing countries have relatively untested potential for oil and gas development. Others possess non-conventional sources of oil such as oil shale and tar sands, for which the extraction technology exists, and whose exploitation is fast becoming economic, given the increased prices of conventional oil, but about which little or nothing is being done. Development of these resources requires massive investment, which should be a matter of high priority in the case of conventional oil and gas, while oil shale and tar sands resources should be studied and evaluated.

There are many important policy issues related to energy development, not the least of them the relative roles of the state and private capital. A doctrinaire approach to this problem has in most cases yielded unsatisfactory results, and there is a trend toward a more pragmatic mixed system which enables governments to tap the large resources and technical expertise of the private sector.

Electricity generation is both one of the factors leading to technology transfer in developing countries, and one of the largest consumers of primary energy. Electric power can be generated through the combustion of low-grade fuels which have little other value, but in doing so such fuels generally substitute for heavy fuel oil, for which there is little other demand in nonindustrialized countries.

Substitution of heavy fuel oil from indigenous refineries by solid fuels or hydro power often prejudices the economics of small oil refineries in developing countries. One way of dealing with this problem is to install secondary refining capacity to enable such plants to convert heavy fuel oil to light products, but doing so doubles the capital cost of the refinery and may not be economic if the total demand for petroleum products is below a certain minimum quantity. It appears that a number of small refineries in developing countries may become increasingly uneconomic to operate and may have to be closed down.

Energy development strategies are examined for three groups of countries: those with a surplus of oil; those with energy supply balances demand; and those with a chronic energy deficit. While no two countries are identical, certain common guidelines can be established with regard to energy policy. Except in the case of OPEC capital surplus countries, these amount to increasing oil exports where possible, and minimizing imports where this is not possible.

Energy demand management is discussed with particular reference to the transport sector. Surprisingly enough, fuel costs appear to be a small proportion of total transport costs, but they are highly visible and are one of the few costs over which the operator has some control. Pricing policy is of great importance in regard to national energy policy. Many countries have illogical energy price patterns which lead to distortions in the energy economy, including encouraging overconsumption of specific forms of energy.

Traditional fuels supply 50-90 percent of total energy demand in developing countries. In many cases there is a crisis in supply of these fuels which is having serious consequences. The issue is only touched on in this report since it is the subject of Staff Working Paper No. 346, "Prospects for Traditional and Non-Conventional Energy Sources in Developing Countries." It is an issue deserving serious policy consideration.

Table of Equivalents

US Measurements	Metric Units
1 foot	0.305 metre
1 mile	1.609 kilometres
1 square mile	2.59 square kilometres
1 gallon	3.7854 litres
1 cubic foot	28.317 litres
1 barrel = 42 gallons	158.99 litres or 0.15899 cubic metres
1000 cubic feet	28.317 cubic metres
1 pound	0.4536 kilogrammes
3412.14 British Thermal Units	1.0 kilowatt-hour or 3.6 Megajoules
3.968 British Thermal Units	1 kilocalorie

Crude Oils

Degrees API	Specific Gravity	Barrels per metric ton
25	0.904	6.98
30	0.876	7.19
35	0.850	7.42
40	0.825	7.64

Petroleum Products

Crude oils	0.80-0.97	8.0-6.6
Gasolines	0.71-0.79	9.0-8.1
Kerosenes	0.78-0.84	8.2-7.6
Gas oils	0.82-0.90	7.8-7.1
Diesel oils	0.82-0.92	7.8-6.9
Fuel oils	0.92-0.99	6.9-6.5

Source: Petroleum Economist.

CHAPTER I

INTRODUCTION[1/]

The fourfold increase in OPEC oil prices in 1973-1974 was a serious blow to the oil importing developing countries. While OPEC oil revenues jumped from $33 billion in 1973 to $108 billion in 1974, the rise in oil prices directly added an estimated $10 billion to the import costs of the oil importing developing countries (OIDCs) in 1974. Their situation has been made even worse by the price increases in 1979.

The oil price rises, world economic recession, and lack of deflationary policies in several OIDCs have led to a large increase in the current account deficit of the OIDCs since 1973. It is very difficult to determine how much of the increases in the OIDCs' current account deficits were "caused" by the OPEC price rise. Estimates by OECD, Citibank and UNCTAD have put the deterioration of the OIDC trade account due to OPEC price increases at $20.3 billion, $20 billion and $40.8 billion respectively, for the two-year period 1974-1975. In general, it appears that 40-60 percent of the rise in the aggregate indebtedness of OIDCs in this period was due to the OPEC price rise. The deficits have been financed by the IMF oil facility, commercial borrowing, and partly from new OPEC lending.

While the external debt of OIDCs has doubled in the past three years (1975-1978) and terms are somewhat harder, these effects are somewhat mitigated by inflationary debt relief and growth in export volumes. Nonetheless, the events of 1979 may again increase the OIDCs' trade deficits. The new round of oil price increases so far in 1979 adds about $9 billion to the annual import costs of the OIDCs, even if there is no change in their oil imports: the current account deficit of the OIDCs now may increase from $32 billion in 1978 to $43 billion in 1979 and may exceed $50 billion in 1980.[2/] These new price increases come at a critical time when an economic slowdown in the industrialized countries reduces the prospects for increased OIDC export earnings needed to pay for oil.

1/ The authors of this paper have drawn freely on both published and internal IBRD Papers in assembling this document. In particular, contributions have been made by the following: E. Friedmann, E. A. Moore, J. Strongman, M. Haug, A. Ezzati, J. Vardi (consultant) and D. Gray (research assistant).

2/ Address by IMF Managing Director in Geneva to UNECOSOC on July 6, 1979.

These events point to the high priority that oil importing developing countries must give to effective energy policies that will reduce the need for oil imports and develop indigenous oil, gas, hydro power and coal. These countries are faced with a double burden--first, that of paying for increasingly costly oil to support the existing economy, and second, very high investment costs to explore and develop new indigenous sources of energy to replace imported oil. Adjustments to the new energy situation need not be sought solely within the energy sector: a vigorous national program to stimulate traditional and nontraditional exports to enable them to better pay for energy imports is an important adjunct to energy policy in these countries.

The problems faced by the OIDCs in obtaining the energy required to sustain acceptable levels of economic growth have greatly increased over the last few years due to higher prices. However, the relative costs of imported oil and domestically produced energy have drastically changed. Over the period 1955-70 crude oil prices f.o.b. Persian Gulf decreased in real terms by about 60 percent. In the early 1970s production costs per barrel of crude oil in non-OPEC countries were between \$2.80 and \$5.00, while the price of OPEC oil was about \$1.80 f.o.b. Persian Gulf, and under \$3.00 c.i.f. the refineries of the importing countries.1/ At the same time, investment costs of new production capacity were typically of the order of \$3,000 - \$4,000 per barrel-day in non-OPEC countries, compared with about \$200 in the Persian Gulf and Libya and \$800 - \$1,000 in other OPEC countries. To be profitable at such price levels, private investment in petroleum development had to be in OPEC countries, so exploration elsewhere tended to be severely restricted. An important further consequence of low oil prices was the switch to petroleum fuels for power generation. The capital requirements for power based on petroleum are much lower than those associated with the alternative sources (hydro, nuclear, geothermal, solar), and somewhat lower than in the case of coal fired plants.

Following the quadrupling of oil prices in 1973-1974 and subsequent increases, c.i.f. costs of crude are now about \$20 per barrel. Future price movements are uncertain but, barring some unforeseen technological breakthrough in the provision of energy, or the collapse of the present artificial structure of crude oil prices, the real price of oil seems unlikely to decline. This assessment is based on the distribution and cost structure within the petroleum industry, the growing world demand for energy, and the costs of providing alternatives to imported oil.

Since imported energy requirements at present consist almost entirely of oil, a reduction in imported oil can be achieved in the short term only at the expense of a reduction in energy supply and, in consequence, lower economic growth, because nonproductive uses of oil (private transport and residential and commercial cooling) are minimal in developing countries.

1/ Historical prices are quoted at actual levels.

For the oil importing developing countries in particular the new level of petroleum prices has two principal implications:

(a) In the short run, given their very limited ability to conserve oil or to substitute other energy sources for petroleum, they must continue to borrow the foreign funds needed in ever-increasing quantities to finance oil imports or else reduce their rate of economic growth.

(b) In the longer term most have the opportunity to develop alternative indigenous energy sources. At present crude oil prices it is now economic for them:

(i) to develop domestic sources of petroleum that were regarded as uneconomic at pre-1973 prices, and to endeavor to expand their known reserves;

(ii) to expand the provision of energy from alternative sources in order to substitute for petroleum-based energy supplies.

Due to the increased cost of oil, countries with large oil-based systems will find it relatively attractive to switch to known alternative indigenous energy sources where this is technically possible. However, the feasibility and desirability of using these alternatives varies greatly with size of a country's energy market and the domestic availability of alternative sources of energy, and depends also on the planning time horizon. Possibilities of substitution for petroleum are more immediate in power production than in other activities. However, even if the system is large enough to take advantage of economies of scale, the development of new power capacity using non-oil resources typically involves much longer lead times (extensive feasibility studies for hydro sites, mining development, regulations for nuclear safety, etc.), longer construction periods and greater potential problems in the supply of manpower and equipment. In addition, hydro and nuclear plants require 50 percent to 100 percent more capital investment, and coal fired plants 30 percent to 40 percent more than comparable oil fired plants.

For the longer term, developing countries need to marshal effectively the financial resources and technical expertise necessary to expand their indigenous energy sources. Before 1973 investments in petroleum development in most oil importing nations depended primarily on the decisions of the international oil companies, whose policy was mainly based on exploiting the lowest-cost world reserves of oil.1/ In the changed circumstances, the oil

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1/ Diversification, security of supply to downstream refining, and marketing were also important objectives.

companies can no longer function as the effective decision makers for many of the OIDCs. The new situation demands national energy policies. While it is now economic to exploit the domestic energy resources of the OIDCs, to do so efficiently it will be necessary to establish priorities for development within an integrated energy program.

Without such programs, the OIDCs may be unable to command the necessary resources. In the case of petroleum there are a number of private consulting groups which can provide solutions for specific technical problems of oil exploration and production in the OIDCs. Similarly, private capital resources are available, particularly for oil production, but without external assistance the prospects of attracting this capital are poor for many of the OIDCs. An immediate requirement of many of these countries is expert help to establish priorities in the context of an overall energy program, then to identify the specific financial and technical needs of a given project, and finally to obtain the appropriate package of services to implement the project successfully.

The following tables show for 1972 and 1976 the imports of crude oil, net imports of petroleum products, the production of indigenous oil and gas liquids, merchandise imports and exports, and the cost of imported fuel as a percentage of merchandise imports, for four groups of non-OPEC developing countries: those which produced oil and/or gas for domestic use in 1977 (Table I.1); those which are potential oil and/or gas producers (Table I.2); those which on present knowledge are deficient in conventional energy resources (Table I.3); and those which are net oil exporters (Table I.4)

Tables I.1 - I.3 demonstrate the significant increase in fuel import costs as a proportion of total import costs, from 7-12 percent on average in 1972 to 15-30 percent on average in 1976.

Table I.1: NON-OPEC DEVELOPING COUNTRIES: OIL AND/OR GAS PRODUCERS (as of 1977)

OIL IMPORTS, PRODUCTION AND TRADE

Oil and/or Gas Producers (as of 1977)	Imports of Crude Oil (mill. metric tons)		Net Imports of Energy Petroleum Products 1/ (mill. metric tons)		Production of Indigenous Crude Oil and Natural-Gas Liquids (mill. metric tons)		Merchandise Imports (c.i.f., mill. current $)		Merchandise Exports (f.o.b., mill. current $)		Imported Fuels as % of Merchandise Imports 2/	
	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976
Afghanistan	0	0	0.3	0.34	0.001	0.007	281	298	90	210	6.8	7.7+
Argentina	1.4	3.0	0.11	0.62	22.5	21.0	1,905	3,031	1,941	3,919	3.7	17.4
Bangladesh	0.85	0.8	0.11	0.11	0	0	189	764	321	414	N.A.	12.4
Barbados	0.14	0.13	- 0.02	0.036	0.001	0.02	141	237	45	104	6	13
Brazil	25.3	41	- 1.64	- 0.52	8.3	8.3	4,783	13,623	3,990	10,128	12.6	30.4
Cameroon, Un. Rep.	0	0	0.26	0.31	0	0	299	609	218	511	5.0	7.8
Chile	3.7	3.5	1.73	- 0.2	1.9	1.3	945	1,684	855	2,071	8.8	20
Colombia	- 2.0	0.93	- 2.0	- 1.2	10.4	7.8	860	1,572	863	1,694	0.3	2.3
India	12.3	13.7	3.3	1.5	7.4	8.7	2,217	5,516	2,401	5,426	11.9	25.7
Morocco	1.76	2.63	0.05	0.1	0.03	0.01	779	2,618	642	1,262	7.0	11.2
Pakistan	3.5	3.2	- 0.25	0.2	0.5	0.3	666	2,181	679	1,144	7.5	18.2
Turkey	8.0	9.6	- 0.6	1.4	3.4	2.6	1,508	4,993	885	1,960	10.3	22.5
Yugoslavia	4.2	8.3	0.7	0.4	3.2	3.9	3,233	7,367	2,237	4,878	5.3	14.4

1/ Computed as energy product imports minus energy product exports with bunkers included as exports. Negative values denote that exports exceed imports.

2/ Fuel imports are almost exclusively crude oil and petroleum products, with metallurgical grade coal in a few instances.

Sources: Oil imports, petroleum product imports and production statistics are from U.N. Statistical Series J-21, 1972-1976.
Import, export and fuel as a percentage of imports data are from U.N. Yearbook of International Trade Statistics 1977.

+ 1975
N.A. = Not available

Table I.2: NON-OPEC DEVELOPING COUNTRIES - POTENTIAL OIL AND/OR GAS PRODUCERS:

OIL IMPORTS, PRODUCTION AND TRADE

	Imports of Crude Oil (mill. met. tons)		Net Imports of Energy Petroleum Products 1/ (mill. met. tons)		Production of Indigenous Crude Oil and Natural Gas Liquids (mill. met. tons)		Merchandise Imports (c.i.f., mill. current $)		Merchandise Exports (f.o.b., mill. current $)		Imported Fuels as % of Merchandise Imports 2/	
	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976
Benin	0	0	0.12	0.10	0	0	93	150^{+}	36	46^{+}	4.2	9.7^{++}
Central African Empire	0	0	0.06	0.04	0	0	34	54	39	58	1.4	1.4
Chad	0	0	0.04	0.06	0	0	61	115	36	62	14.4	15.6^{++}
Costa Rica	0.5	0.3	0.05	0.35	0	0	343	775	279	584	4.8	10.3^{+}
El Salvador	0.5	0.7	0	0	0	0	278	718	302	721	4.4	8.3^{+}
Ethiopia	0.6	0.5	- 0.16	- 0.2	0	0	188	353	166	278	5.9	16.4^{+}
Fiji	0	0	0.2	0.15	0	0	159	263	74	127	9.8	16.0
Ghana	1.2	1.14	- 0.3	- 0.37	0	0	290	805^{+}	390	760	10.2	15.0^{+}
Guatemala	0.9	0.7	- 0.07	0.3	0	0	324	839	338	760	7.1	13.7^{+}
Guinea	0	0	0.3	0.3	0	0	32	37	3	6	N.A.	9.4
Guyana	0	0	0.5	0.55	0	0	143	364	147	269	9.3	18.2^{++}
Haiti	0	0	0.10	0.08	0	0	60	121^{+}	42	127	6.0	8.5
Honduras	0.6	0.4	- 0.16	- 0.01	0	0	193	453	193	392	9.6	10.2
Ivory Coast	1.1	1.5	- 0.12	- 0.22	0	0	449	1,296	553	1,620	6.3	12.5
Kenya	2.5	2.5	- 1.4	- 1.3	0	0	497	941	267	665	11.3	26.2
Korea, Rep.	12.6	18.3	- 1.4	- 3.1	0	0	2,522	8,774	1,624	7,715	8.4	19.9
Liberia	0.6	0.5	- 0.07	- 0.08	0	0	205	295	244	460	6.7	14.5^{+}
Madagascar	0.63	0.55	- 0.26	- 0.2	0	0	205	367^{+}	166	294^{+}	7.6	19.5^{+}
Malawi	0	0	0.12	0.12	0	0	128	205	79	148	7.7	12.4
Mali	0	0	0.08	0.1	0	0	70	150	34	85	10.3	14.0
Mauritania	0	0	0.1	0.1	0	0	71	180	107	178	6.1	N.A.
Mozambique	0.77	0.4	- 0.24	0	0	0	330	417^{+}	177	202^{+}	7.1	9.6^{++}
Nepal	0	0	0.09	0.07	0	0	79	163	41	97	N.A.	N.A.
Nicaragua	0.5	0.7	0.04	0.06	0	0	218	532	246	542	7.2	12.9
Niger	0	0	0.08	0.1	0	0	66	99^{+}	54	91^{+}	8.6	11.7^{+}
Panama (excluding C.Z.)	4.0	2.8	- 3.1	- 1.6	0	0	440	838	121	227	16.6	40.3
Papua New Guinea	0	0	0.4	0.5	0	0	295	430	217	573	4.9	8.4^{++}
Paraguay	0.2	0.2	0.02	0.08	0	0	70	187	66	178	N.A.	N.A.
Philippines	9.2	9.6	-0.9	0.4	0	0	1,485	3,953	1,168	2,574	12.6	23.4
Senegal	0.6	0.7	- 0.2	- 0.2	0	0	279	576^{+}	216	461^{+}	5.5	29.2^{+}
Sierra Leone	0.3	0.35	- 0.18	- 0.1	0	0	121	153	117	111	7.2	11.1^{++}
Sudan	1.1	1.15	0.68	0.56	0	0	353	980	360	554	7.2	3.4^{+}
Tanzania, U.R.	0.8	1.0	0.16	0.1^{+}	0	0	356	557	300	459	8.9	18.2
Thailand	6.5	7.4	0.13	0.94	0.006	0.009	1,484	3,572	1,081	2,980	10	22.8
Uganda	0	0	0.4	0.3	0	0	114	80	261	359	0.3	1.1
Uruguay	1.7	1.9	0.24	0.1	0	0	212	599	214	546	N.A.	34.6

1/ Computed as energy product imports minus energy product exports with bunkers included as exports. Negative values denote that exports exceed imports.

2/ Fuel imports are almost exclusively crude oil and petroleum products, with metallurgical grade coal in a few instances.

\+ 1975

++ 1974

Sources: Oil imports, petroleum product imports and production statistics are from U.N. Statistical Series J-21, 1972-1976.
Import, export and fuel as a percentage of imports data are from U.N. Yearbook of International Trade Statistics 1977.

NA = Not available.

Table I.3: NON-OPEC DEVELOPING COUNTRIES DEFICIENT IN INDIGENOUS ENERGY RESOURCES:

OIL IMPORTS, PRODUCTION AND TRADE

	Imports of Crude Oil (mill. met. tons)		Net Imports of Energy Petroleum Products (mill. met. tons) 1/		Production of Indigenous Crude Oil and Natural Gas Liquids (mill. met. tons)		Merchandise Imports (c.i.f., mill. current $)		Merchandise Exports (f.o.b., mill. current $)		Imported Fuels as % of Merchandise Imports 2/	
	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976
Burundi	0	0	0.12	0.02	0	0	31	58	26	55	N.A.	N.A.
Cyprus	0.6	0.4	0.02	0.25	0	0	315	430	134	257	6.9	15.1
Dominican Republic	0.7	1.3	1.5	0.8	0	0	338	764	348	716	8+++	N.A.
Gambia	0	0	0.02	0.03	0	0	25	74	19	35	3.5	8.6+
Jamaica	1.9	1.5	0.32	1.28	0	0	620	913	378	633	9.0	22.6
Jordan	0.6	1.2	0.007	- 0.03	0	0	267	1,022	48	209	4.8	10.9
Lebanon	2.1	2.15+	- 0.56	- 0.32+	0	0	849	N.A.	350	N.A.	5.4	N.A.
Mauritius	0	0	0.12	0.22	0	0	120	359	107	265	7.8	N.A.
Rwanda	0	0	0.02	0.03	0	0	35	103	19	81	7.7	10.9
Singapore	19.77	21.3	-15.9	-13	0	0	3,398	9,070	2,191	6,585	14.5	27.4
Somalia	0	0	0.07	0.1	0	0	75	162+	43	85	4.1	6.1++
Sri Lanka	1.8	1.5	- 0.38	- 0.5	0	0	351	553	338	567	1.4+++	23.7
Surinam	0	0	0.5	0.6	0	0	145	262+	171	277+	12.4	N.A.
Upper Volta	0	0	0.06	0.07	0	0	69	145	20	53	7.5	7.9+
Yemen	0	0	0.08	0.21	0	0	80	410	4	8	10	14.5
Yemen Democratic	3.4	1.9	- 2.9	- 1.4	0	0	149	414	108	249	N.A.	N.A.

1/ Proven and probable indigenous commercial energy resources, which are at present competitive with imported oil, are small relative to commercial energy demand in these countries.

2/ Computed as energy product imports minus energy product exports with bunkers included as exports. Negative values denote that exports exceed imports.

3/ Fuel imports are almost exclusively crude oil and petroleum products, with metallurgical grade coal in a few instances.

\+ 1975

++ 1974

+++ 1971

NA = Not available.

Table I.4: NON-OPEC DEVELOPING COUNTRIES: NET OIL IMPORTERS

OIL PRODUCTION AND TRADE

Oil and/or Gas Net Exporters	Exports of Crude Oil (mill. metric tons)		Net Energy Exports of Petroleum Products (mill. metric tons) 1/		Production of Crude Oil and Natural Gas Liquids (mill. metric tons)		Merchandise Imports (c.i.f., mill. current $)		Merchandise Exports (f.o.b., mill. current $)	
	1972	1976	1972	1976	1972	1976	1972	1976	1972	1976
Angola	6.8	3.8^{+}	- 0.1	0.05	7.1	4.5	397	625^{++}	516	1,227
Bahrain	0	0	10.3	9.3	11.8^{*}	10.9^{*}	377	1,668	323	1,517
Bolivia	1.4	1.0	0	0.02	2.1	1.9	173	558^{+}	201	446^{+}
Brunei	8.7	10.0	0.002	0.003	8.9	10.2	106	269^{+}	176	$1,023^{+}$
Burma	- 0.1	0	0	0	1.0	1.2	159	218^{+}	120	158^{+}
Congo	0.29	1.9	- 0.1	- 0.1	0.3	2.0	90	156	52	182
Egypt	5.6	6.7	- 0.46	0.7	10.7	16.8	899	3,808	825	1,522
Malaysia	0.16	0	- 0.9	- 0.8	2.8^{*}	3.6^{*}	1,611	3,825	1,722	5,293
Mexico	- 1.3	6.2	- 1.34	- 2.64	24.3	44.8	2,718	6,030	1,845	3,302
Oman	14.1	18.3	- 0.1	- 0.3	14.1	18.3	161	1,102	242	1,575
Peru	0.15	0.27	- 0.1	- 0.1	3.3	3.8	797	1,780	943	1,304
Syrian Arab Republic	4.2	9.6	0.02	0.4	5.9	10.0	545	1,986	287	1,065
Trinidad & Tobago	2	6.3	18.0	14.4	22.0^{*}	22.5^{*}	766	1,976	558	2,214
Tunisia	3.7	3.7	- 0.34	- 0.33	4.0	3.7	465	1,529	315	788
Zaire	0	1.0	- 0.1	- 0.25	0	1.25	766	827	738	930

1/ Computed as energy product exports, plus bunkers, minus energy product imports. Negative values denote that imports exceed exports.

* Crude oil imports included.

\+ 1975

++ 1974

NA = Not available.

A. Current Outlook

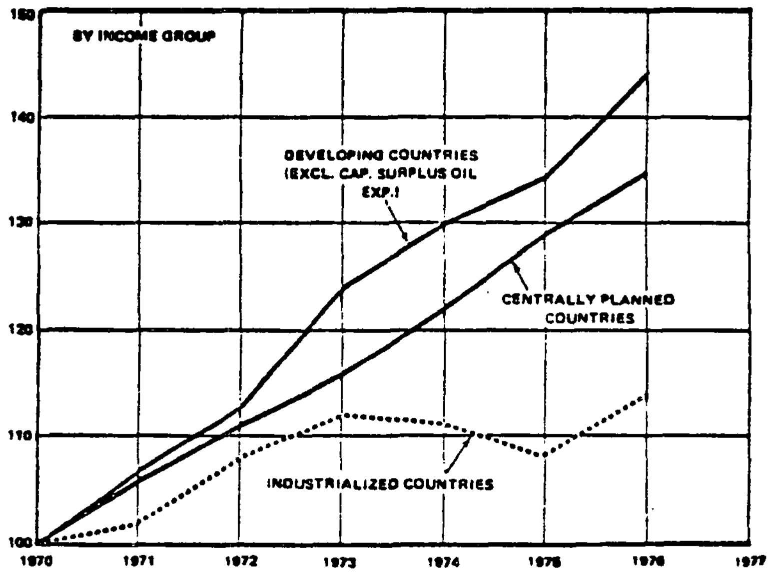
Developing countries in 1976 accounted for about 12 percent of world primary energy consumption, and 15 percent of world petroleum consumption. These countries imported 7 million b/d of petroleum, which is about 19 percent of world gross imports of petroleum. Although this currently is only a small share, the importance of the developing countries in the global energy balance rests on the prospect that their energy requirements are likely to increase at a much faster rate than those of the rest of the world (See Graph I.1). Several factors account for this expectation: (a) developing countries are expected to maintain higher economic growth rates than the rest of the world; (b) industrialization and urbanization are likely to make these economies more energy intensive; (c) as income levels increase, the use of various energy consuming amenities (automobiles, electric appliances, etc.) could increase rapidly from the present low levels; (d) substitution of commercial energy for non-commercial energy is likely to continue, thus adding to the demand for commercial energy.1/

Forty-eight of the 74 developing countries which import oil depend on it for at least 90 percent of their commercial energy requirements; only four (India, Korea, Pakistan and Zambia) are less than 50 percent dependent on oil owing to the extensive use of coal, natural gas or hydro-electric power. The oil deficit of these 74 countries as a group is now thought to be larger than was estimated in 1977. Although their oil production has increased, oil consumption in these countries is increasing more rapidly yet, owing to their rate of economic growth. Many developing countries are passing into the energy-intensive phase which the developed countries experienced during their rapid industrialization and urban growth. However, unless their energy deficit can be narrowed by exploiting indigenous sources of energy more fully, scarce foreign exchange will have to be diverted to pay for energy imports, thus keeping economic growth slower than it otherwise would be.

1/ "Commercial" energy comprises those energy forms in which there is a large international and domestic market, and which supply the needs of a modern industrial economy, i.e., petroleum fuels, natural gas, electricity, coal, hydro. "Non-commercial" energy comprises all those fuels commonly used in the non-industrial or traditional sector of the economy, such as wood, charcoal, crop residues, and animal dung. The term is somewhat misleading since these commodities often have a cash value and enter into commerce, but their procurement and availability does not depend on the application of modern technology. The distinction between "conventional" and "non-conventional" energy sources is also arbitrary and somewhat misleading. In general, all those energy sources listed above, which are in every day use in most countries, are regarded as "conventional." Those energy sources which are not widely used at the present time, e.g., solar energy, oil shale, tar sands, biogas, ethyl alcohol, are regarded as being "non-conventional."

Graph I.1: ENERGY: INDEX OF CONSUMPTION (1970 = 100)

(Million barrels per day of oil equivalent)



B. Toward a New Energy Consumption Pattern

At present crude oil accounts for 90 percent of international trade in energy. The share of petroleum in consumption is expected to fall somewhat in all major regions, except in some oil exporting countries, but the rate of projected fuel substitution is small; petroleum's share of international trade in energy is unlikely to fall by more than 5 percent of the total between 1980 and 1990. This very slow transition results from lack of economical alternative technologies and the constraints imposed by existing economic infrastructure, especially in transportation and residential usage. The 1990s will probably witness more substantial substitution for petroleum-based fuels and a general trend toward a more diversified energy market.

Lead times and life spans of major energy resources and consumers are very long. To design and construct energy resources such as coal mines, oil field installations, or refineries, or major energy consumers such as power stations, petrochemical fertilizer and other industrial complexes, as well as major transportation systems, may take from three to six years, while the planned life span is 25 to 35 years. Therefore, many decisions to be made now will still have effects in the year 2015. The transition toward a more varied energy supply will therefore require two decades or more to complete.

C. Traditional Fuels

Developing countries depend on traditional fuels such as firewood, crop residues, and animal dung to meet between 50 and 90 percent of their domestic energy needs, principally for cooking. As the population in these countries increases, supplies of these fuels are becoming inadequate in many cases. The pressure of demand for firewood has resulted in severe deforestation, especially in countries with a semi-arid climate where forest regeneration is slow. Often deforestation results in loss of top soil, and this, combined with overgrazing by browsing animals such as sheep and goats, prevents any regrowth. The result is an increasing deficit of fuels available to the poorer sections of the population for cooking.

In many developing countries where the domestic sector is supplied by traditional fuels, obtaining such fuels takes up an increasing proportion of the domestic budget, either in cash or in time expended in gathering fuel. In urban areas where the transition has been made to commercial fuels, the price of these has become a sensitive political issue.

The so-called "firewood crisis", relating to the growing scarcity of traditional fuels used in the domestic sector, is a serious issue which calls for consideration in planning and policy decisions. All too often traditional energy sources are neglected by governments because their use generally is not recorded and reliable statistics are therefore not available. These sources are estimated to account for over 90 percent of total energy demand in Nepal, Tanzania, and Mali. In Africa (excluding South Africa) traditional fuels are believed to supply more than sixty-five percent of total energy demand. The effects of energy scarcity in this sector are therefore bound to be felt by the whole population.

CHAPTER II

ENERGY DEVELOPMENT STRATEGY AND THE NATIONAL ENERGY PLAN

The main consideration in setting the energy development strategy of a country is its energy resource endowment. Developing countries possess energy resources of both renewable and non-renewable character, such as oil, gas, coal, hydro power, uranium, geothermal energy, solar energy and non-commercial fuels. Very few are so deficient in energy resources that no further development is possible. However, energy resources in these countries are often either not proven or not fully developed. These potential energy resources, if developed, could reduce or eliminate the dependence on imported energy. It is a prime requirement of good energy planning to identify these potential resources and plan for their investigation.

A. Resource Characteristics and Related Development Strategy

Primary energy resources differ markedly from one another in their location with respect to markets, ease of transport, export potential, effects on the environment, flexibility with respect to end uses, potential for substitution, the lead times required for development, and technology. Resources which cannot readily be transported or exported should be regarded as destined for local consumption; examples are low-grade coal and lignite, hydro power and natural gas. Exports of the latter two generally require overland links with adjoining countries. The production of liquefied natural gas (LNG) requires very high investment, and very large gas reserves, to be economic, and brings a relatively low return to the producer. If local energy demand is not such as to justify development of these non-exportable primary energy resources, the potential for development of energy-intensive export industry based on their use should be investigated.

Energy demand management by encouraging the substitution of one primary energy form for another depends on the characteristics of the primary energy resources involved. Generally, one solid fuel can readily substitute for another, but solid fuels cannot easily substitute for liquid fuels, if at all. At present the greatest potential for substitution is in electric power generation and the least potential for substitution is in the transport sector. Fuel substitution in oil fired power generating plants is limited to natural gas unless the boiler is rebuilt to burn solid fuels - a step which is usually not economically justifiable.

Energy supplies can be diversified in several ways:

(a) Use of both domestic and imported energy,

(b) Energy imports from different sources of supply,

(c) Employment of a diversity of primary energy sources.

A country's ability to diversify its energy economy depends on the type and nature of indigenous primary energy resources available and the degree to which they have been developed, the ability to pay for energy imports, and the pattern of demand in the domestic energy market.

Current and Future Energy Export Potential and Related Strategies

Since oil will probably enjoy a ready export market for the foreseeable future, some oil exporting developing countries which possess natural gas and coal are expected to expand production of these fuels to meet internal energy consumption so as to release oil for export. Exports of gas and coal may also be possible. Table II-1 shows preliminary estimates of the NOIDCs' potential exports of fossil fuels by country and commodity.

The estimates are derived from projections of production and internal consumption in each country. When a country has no significant alternative sources of energy to those already being produced, internal demand for each fuel is assumed to grow at the same rate as the total demand for energy.

Most existing coal development projects are designed for domestic markets rather than for export, because coal has a lower calorific value and is more expensive to transport than oil. However, Japan and Europe both offer expanding markets for coal exports for metallurgical coking coal and for good quality steam coal. At the moment, few developing countries are cost-competitive with coal exporters such as Australia, Canada, Poland, South Africa and the United States, but in the medium to long term LDCs could become significant exporters, either to industrialized markets or to other LDCs. Projects with important export components are being implemented in Colombia and Vietnam; other potential coal exporters are Indonesia, Swaziland and Chile. Financial, technical and market constraints, combined with lack of transport and trans-shipment facilities, will probably delay the implementation of some potential projects.

Energy Surplus Countries

The options for major energy exporting countries, which at present are exclusively those with abundant oil resources and oil production well in excess of their domestic consumption of petroleum products, are related mainly to the wise investment of the revenues accruing from such exports. Numerous countries have enjoyed a brief spell of prosperity stemming from the export of some commodity which was, at that time, indispensable and in short supply, for example nitrates, tin and rubber. In each case the boom has collapsed when alternative sources of supply were found or substitutes developed. There is reason to believe that in the long run the prosperity of some of the oil exporting countries will prove no less transient as their resources become depleted and world demand perforce shifts to alternative energy sources.

Table II.1: NET EXPORT POTENTIAL OF FOSSIL ENERGY IN NON-OPEC DEVELOPING COUNTRIES

	Actual	Projected		
	1975	1980	1985	1990
Petroleum, '000 b/d of crude oil equivalent				
Angola	130	185	200	222
Congo	33	95	133	190
Zaire	-17	32	78	116
Egypt	-21	390	820	1,040
Syria	135	154	124	90
Tunisia	74	89	90	92
Bahrain	15	19	1	-30
Oman	319	314	361	387
Malaysia	-5	60	60	60
Brunei	176	196	244	291
Bolivia	24	45	65	109
Mexico	75	800	1,000	700
Trinidad/Tobago	155	153	114	155
Total	1,093	2,532	3,290	3,422
Natural Gas, '000 b/d of crude oil equivalent				
Egypt	0	0	20	50
Tunisia	0	0	50	50
Oman	0	10	15	20
Bangladesh	0	0	0	25
India	0	0	23	30
Afghanistan	51	59	66	79
Malaysia	-3	130	140	140
Brunei	96	104	122	168
Bolivia	25	25	34	56
Mexico	-4	70	270	340
Total	165	398	740	958
Coal, million metric tons of hard coal				
Botswana	.1	.2	.2	.3
Mozambique	.1	.4	2.2	3.5
Swaziland	.1	.4	1.3	2.0
Rhodesia	.2	.3	.4	.4
South Africa	2.8	3.5	4.0	4.5
India	.4	2.0	5.0	10.0
Vietnam	.5	1.5	2.5	4.0
Colombia	0	0	2.5	8.0
Total	4.2	8.3	18.1	32.7

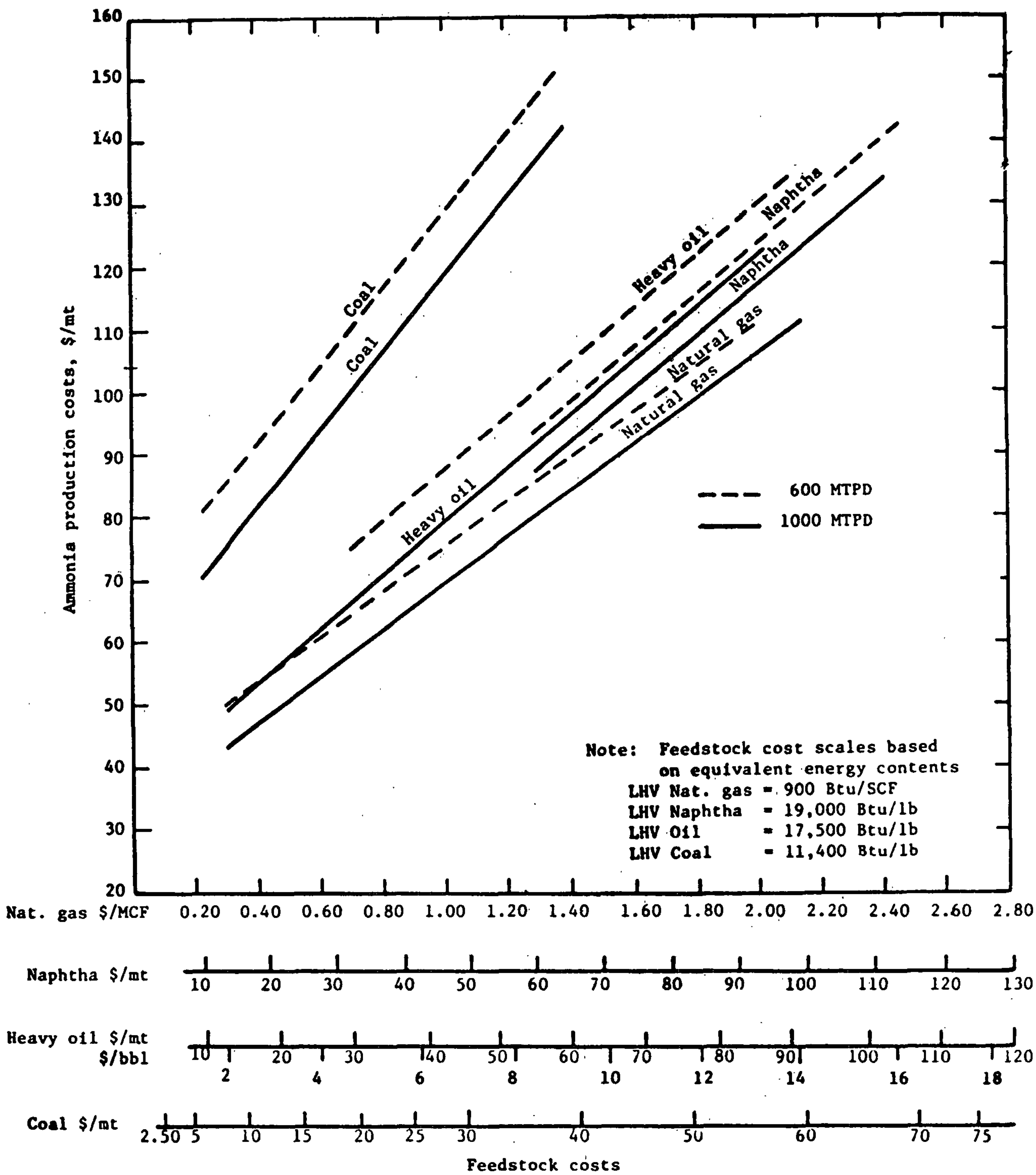
One option frequently overlooked by the governments of oil exporting developing countries is the need to reinvest a substantial portion of the present revenue in further petroleum exploration and development in order to avoid a premature decline into oil-deficit status. Many former oil exporters have become net energy importers as a result of neglecting exploration while depleting their known reserves. Individual oil fields for the most part have an economic life of two to three decades, while an oil producing province may have a life of a century or more if there is sufficient reinvestment in exploration and development. Exploratory activity for oil and gas has been declining in developing countries in recent years, despite the economic attraction of developing new production at present prices. In part this is attributable to political and economic conditions unattractive to private capital, which formerly undertook the bulk of exploratory activity, and which have caused a decline in private investment in exploration. This decline in private investment in petroleum exploration has been left uncompensated by public investment, so that in many cases oil production may start to decline within the next few years. This natural production decline combined with a rapid increse in internal demand for petroleum products may lead to a relatively rapid decline in exportable oil surpluses and export revenue.

Another option for oil producers is to invest in other sectors of the economy which are both productive and long lived. Venezuela has invested in renewable resources, in agriculture, forestry and fisheries. Investment in industry is likely to yield greater returns if it is based on the processing of locally produced raw materials or indigenous skills, rather than on imported commodities.

An example of an energy-intensive industry in which energy surplus countries would have a comparative advantage is nitrogen fertilizer (ammonia) production. For nitrogen fertilizer, more than phosphate and potash fertilizers, energy is a very important component of production costs in terms of both hydrocarbon feedstock and fuel. Natural gas, oil, naphtha and coal can be used to produce synthetic ammonia. The relation between feedstock prices and ammonia production costs is given in Figure II-[illegible]. If the price of gas, oil or naphtha feedstock increases 100%, ammonia production costs increase approximately 60%.

An important development option which the energy surplus developing countries should examine is that of establishing large-scale energy-intensive metal extraction industries based, if need be, on imported mineral raw materials, with the processed metals being exported. A classical example is the aluminum industry, in which electricity used in aluminum smelting accounts for about 30% of the direct production costs (excluding financial charges). Clearly it might be attractive economically for new aluminum smelting capacity to be located in energy surplus countries, particularly those with large associated gas production or hydro resources.

Figure II.1: AMMONIA PRODUCTION COSTS VERSUS FEEDSTOCK COSTS



1977 Dollars
Source: "Coal Based Ammonia Production", Fertilizer Industry Roundtable, 1977.

Alumina production from bauxite is also rather energy intensive - primarily in terms of thermal energy rather than electrical energy. Thermal energy costs represent about 25% of the direct production costs of alumina excluding financial charges, based on fuel oil costs of about US$11/barrel. In those energy surplus countries with significant associated natural gas production the possibility of having a fully integrated alumina/aluminum ingot industry based on imported bauxite raw material is an industrialization path worth examining in depth.

Those few countries which are major oil exporters but which have only a small population, and little prospect of productive investment in their own territories, have little alternative other than to invest their revenues in external assets. This in turn calls for the development of expertise in international financial investment in order to ensure that the assets are not lost by the accidents of commercial failure, currency devaluation or outright expropriation.

An option which merits consideration even by the major oil exporters is the development of alternative energy supplies to meet internal energy demand, where natural resources are available for this purpose. The revenue obtained from oil exports far exceeds that from the export of any other commodity, so that the development of alternative energy sources may have beneficial effects by liberating additional oil for export.

Energy-balanced countries

There is a group of developing countries whose energy production more or less balances domestic demand, so that they may be either minor importers or exporters, depending on internal changes in supply and demand. In general these countries have a substantial modern sector and a relatively large population, so that energy supply must increase in step with development if the country is not to move permanently into energy deficit. How far this can be achieved depends upon the extent of indigenous energy supplies, but the exhaustion of these supplies can be postponed and its ill effects compensated for by intelligent and informed energy and economic planning.

Energy options for these countries include planned development of indigenous energy sources, energy demand management, the adoption of policies designed to foster efficient energy use, and the establishment of industries which can earn foreign exchange to pay for needed energy imports when indigenous supplies prove inadequate. Since many of these countries are fairly advanced in the development cycle such options are feasible, although it must be admitted that few governments actually follow such courses consciously. The result of failure to follow a rational energy policy is usually a lopsided development which results in a rapidly increasing oil import bill, to pay for which resources must be obtained by starving other essential sectors of the economy of investment funds.

Energy Deficient Countries

The third group of countries are those whose energy needs must consistently be met by imports. They vary widely in terms of population size, degree of development, availability of indigenous energy resources, and the availability of exportable commodities to pay for imported oil. The group includes many of the poorest countries with the most limited energy resources, but also some which have the potential to produce oil and gas if the necessary exploration can be undertaken.

One obvious option in this group is energy demand management to reduce the need for imported oil. This can be achieved by government regulation, by energy pricing, or by scarcity - simply not importing more than a certain quantity and allocating supplies to essential consumers.

Another option open to this group of countries is the development of exports with which to pay for imported oil. These exports may be minerals, forestry products, agricultural produce, tourism, or manufactures. In each case, however, a further element of uncertainty is introduced in that international demand and prices of these exports may fluctuate widely while the cost of imported oil continues to rise. It is essential, therefore, in considering such projects, to ensure that the value added is sufficient to cover not only the cost of the required energy imports, but also the import component of the producing facility, and leave a margin to cover energy imports needed for other sectors. Without this, the energy import situation will remain unchanged, or may even be worsened.

Basic energy strategy for countries which are not capital surplus oil producers may be summed up as follows:

(a) Maximize exports of oil if possible.

(b) Minimize imports of oil if domestic production is inadequate or nonexistent.

(c) Investigate and develop indigenous energy resources.

(d) In energy resource-deficient countries, examine by what means foreign currency can be generated to pay for energy imports.

(e) Pursue energy conservation policies, including the use of fiscal and price inducements.

(f) Avoid setting up energy-intensive industries if indigenous energy resources are not available to supply them.

Traditional energy is largely ignored by planners in developing countries, but it merits high priority. It needs little imagination to visualize what would happen if demand for traditional energy sources were to be shifted to the commercial sector, yet this is what may happen if no steps are taken to improve their availability.

Because energy pervades all aspects of national economic life, the formulation of national energy plans and policies is a complex exercise. It requires professional capability to evaluate alternative strategies in terms of costs and benefits, security of supply, effects on growth, employment, inflation, environmental quality, balance of payments and other critical parameters. Added to this, the various elements of an energy program have to be pulled together and fitted into a government's overall economic and financial plans. Finally, in order to ensure that the energy plan is implemented, it is essential that appropriate institutional structures are established in the energy sector.

Integrated energy planning of the type described above is fairly new, and is not yet a well developed art or science. The problem of energy planning in developing countries is made more difficult by a lack of data on the detailed structure of energy demand--by energy type--and a lack of data on these countries' energy resource potential. Developing country governments are establishing institutions to formulate and prepare national energy plans as well as to oversee the implementation of the national energy policy. But in several cases these new agencies lack stature and authority effectively to control powerful and well-established energy subsector organizations, such as national electricity or national oil companies, which are often almost states within states.

B. National Energy Planning

National energy planning and analysis should not be initiated simply by collecting energy data and building econometric models. The initial problem is to decide which issues are to be analyzed and what criteria will be applied in deciding priorities. For example, in oil importing developing countries, is the key policy issue displacement of imported oils? If so, by what means? One of the major problems experienced by oil importing developing countries is in fact the payment for petroleum imports and the difficulty of reducing these imports in the short term without restricting economic growth. The question therefore arises as to what role "non-energy" strategies should play in adjusting to the oil payment problems - for example whether a vigorous drive to increase foreign exchange earnings from traditional and non-traditional exports is called for. In this context, it is important that the national energy plan is not confined to the energy sector, at least in addressing the problem of imported petroleum, but instead considers developments in the economy as a whole.

The national energy plan should address energy issues on three different levels:

(a) National energy policies in relation to other national goals, e.g., energy investments relative to investments in other sectors, the role of energy prices in the economy, the impact on the balance of payments, and the scale of foreign borrowing to develop the energy sector.

(b) Relationships between different subsectors within the energy sector, e.g., rates of oil and gas development versus coal development, depletion rates of reserves of fossil fuels, and assessing the role of energy demand management in each sector of economic activity. In addition, the role of prices in energy conservation and primary fuels development must be studied.

(c) Optimal policy within the domain of each subsector, e.g., the optimal expansion of a power generating system or of petroleum refining capacity, including consideration of the relative role of public and private investment in the sector.

The first level assures that whatever the national energy strategy may be, it will be consistent with other national priorities. This includes assessing the economic, social and environmental effects of the energy strategy, as well as seeking to reconcile its demands for scarce skilled manpower and financial resources with those of other critical sectors of the economy.

The second level deals with issues such as the manner in which energy supply should be diversified, and the optimal mix between the different energy subsectors (such as the role of electricity supplies in total commercial energy supplies). Also included at this level is an analysis of energy demand, forecasting future energy consumption by energy type and by sector. In preparing forecasts of future demand it is particularly important to take account of anticipated structural changes, the role of energy conservation, and estimates of the effects of various price levels on demand for different energy forms. Computer models can be of use in this type of analysis.

The third level concerns the management of each energy subsector.

Information Requirements

In order to prepare a national energy plan it is necessary to have a detailed knowledge of the structure of total and commercial energy demand, by energy type and by category and end-use, and to have some sort of inventory of national energy resources. One analytical tool which might be of value in developing countries, and especially the oil importing developing countries, is a National Energy Accounting System (NEAS). Such an energy accounting system must be designed so that the flow of all energy forms between different sectors of the economy and for different end-uses may be determined. The NEAS should also provide information on the prices of all energy forms at the different energy supply and demand points of the economy.

The NEAS is useful for several reasons. First, it provides a means of monitoring and describing energy consumption. Secondly, it is required to construct computer models which can help estimate changes in the nature of energy use and the amount of energy used. Thirdly, it is needed to assess the effects of changes in energy policy.

In addition to the energy flows account and energy prices account, the NEAS should also contain an account of the inventory of major energy consuming equipment by sectors.

Personnel Requirements

Initially, only a small group of experts should be established, consisting of specialists in the basic areas of energy supply, demand, and analysis of economic and social effects. The work of this group should be coordinated with other government departments, including those dealing with development of indigenous energy resources. If there are insufficient contacts between the energy planners and other organizations, energy planning will become an abstract intellectual exercise devoid of real significance.

Ultimate responsibility for carrying out energy studies and formulating energy policies can only rest with national authorities: in some cases data may be considered to be of strategic or commercial value and cannot readily be made public; in most cases policy decisions involve political, security and value judgments not entirely quantifiable and not amenable to objective evaluation by foreigners. For these reasons, the most appropriate role for external technical assistance in energy planning is that of a consultant group advising national policymakers on how to carry out the studies which the latter consider to be of primary importance in structuring their energy policies. Effective energy planning requires the use of high quality specialized analysts using the best techniques available in the field of energy policy planning. In many developing countries it will be necessary to obtain specialized personnel from external sources to supplement national personnel in the initial stages.

Management of the energy planning group is an important ingredient for the successful implementation of energy options in developing countries. The creation of a cadre of capable managers requires training in domestic institutions, or opportunities to train individuals in the institutions of developed countries. This can be accomplished through broad bilateral or multilateral arrangements between developing and developed countries. Arrangements could be made so as to cover the exchange of personnel and information. Adequate salary levels are also necessary to retain skilled and trained personnel, who will otherwise move elsewhere.

At this time very few countries have at their disposal all the requirements for detailed energy planning, such as the data base, resource inventory, the methodology, the skilled manpower and the institutions to handle these tasks; in those that have, experience in using these resources for policy formulation is of recent origin and is rapidly evolving. This does not mean, however, that useful results cannot be obtained with limited resources. Much can be achieved by the application of rational thought to the solution of the most obvious problems.

Institutional Relationships

For energy planning to be effective it is of particular importance that the agency responsible for national energy planning and policy analysis is able to influence the major energy producing institutions in the country on matters of energy policy. There is much to be said in favor of having all the major energy producing entities and the national energy policy agency in a developing country report to the same minister, the energy minister. However, where this is not considered feasible or desirable, close coordination between all government departments dealing with energy supply and consumption is essential to successful energy planning. The energy planning group should have prime responsibility for this coordination.

Planning under Uncertainties

Every planning process involves decision making under uncertainties. It seems, however, that the magnitude of the problem is greater in energy planning than in many other sectors because of the severity and number of uncertainties involved. These include:

(a) Very long planning horizon

Some decisions in the energy sector have consequences 25-35 years after the decisions have been made. Power stations, hydroelectric installations, mines, and transportation systems and industries with high energy consumption are still in operation many years after decisions have been made to construct them. All such decisions are based on the present values of parameters such as fuel prices, which may be very different in years to come.

(b) Long lead time

Another dimension of the same problem is the long lead time for construction of the systems, both on the supply and the demand side. Studies regarding major system expansions may take a number of years; obtaining the necessary licenses and permits, and planning, designing and constructing is again a long process. A major component of the energy system may require ten years from initial planning to the time operation starts. Hence, between the time a decision is made and the time the system is withdrawn from service, up to 40 years or more may elapse. Historically, the transition period during which the main industrial fuel changed first from wood to coal, then from coal to oil and gas, took in each case some 50 years or more. The change away from oil and gas to some diversified range of primary energy sources will take a similar period and is unlikely to be completed until some time around 2000 to 2020.

(c) Changing prices

As the world witnessed in 1973 and subsequently, fuels traded on the international market, especially crude oil, may be subject to substantial and unpredictable price increases. The transportation cost of internationally traded fuels is a major component in the cost of imported energy, and is subject to sudden and significant price fluctuations. Most decisions in the energy sector are based on the present costs of energy in relation to those of other goods and services, as well as the relative prices of different energy sources. These prices can vary substantially over time. Large relative price changes can be expected during periods of energy transition such as the one which the world now faces. The price of imported crude oil, in particular, is largely unpredictable because the present system of price control bears no relation to production costs, but is determined largely by political considerations.

(d) Changing technology

The technology available both in the energy supply and consumption sectors is changing qualitatively and quantitatively all the time. Advances in system performance, processes, consumption of energy, efficient and different use of energy are made all the time. In many instances, better, cheaper, and more efficient systems are made available. It is safe to say that most energy systems become technologically obsolete long before they are actually withdrawn from service. A typical example is the change in function from base load to peak load of electricity generating plants as they become relatively less efficient during their lifetime.

(e) Changes in supply

Many countries without developed energy resources nevertheless have undeveloped resources; some will find in the future oil, gas or coal of which they are unaware at present. A country may make major investments in systems which are designed to use one sort of energy, e.g., nuclear power, only to find a number of years later that it possesses indigenous resources of a different character which might be more economic to utilize. A narrow commitment to any one energy source is therefore undesirable.

(f) Changes in demand

Demand for energy has an ever-changing pattern. Countries may tune their systems to a certain demand pattern, and this pattern will change in the future as development proceeds and technological changes are introduced. Inventions such as the internal combustion engine, refrigeration and air conditioning, or new processes to produce steel with non-coking coal, are past examples of technological developments which have resulted in substantial changes in energy demand.

For all the reasons cited above, countries should try not to lock themselves into rigid or inflexible systems either in energy demand or supply. In developing countries the relatively low levels of current consumption combined with high rates of growth of energy consumption permit considerable flexibility in adapting to present and foreseeable trends in energy demand and supply.

(g) Periodic review of the plan

Initially, it may be unavoidable to work with insufficient data when drawing up a national energy plan. However, the problems created by planning under this and the other uncertainties render it desirable for every country to undertake a systematic and periodic review of all its energy options. Decisions must be taken in the light of the information available, but this should not preclude a reevaluation of policies in the light of newly available data.

Evaluation of indigenous energy resources

Parallel with the gathering of data on the nature of energy demand, it is important to carry out an assessment of indigenous energy resources in a country. This is usually a fairly lengthy process, spread over several years, but the sooner it is commenced, the sooner the results can be incorporated in the plan. One of the problems in formulating an energy plan in developing countries is the lack of reliable estimates of the amount of energy resources, even when the latter are known to exist. The problem is most difficult to resolve in the case of fossil fuel resources, especially oil and gas, since the cost of exploring for them and defining the reserves is too great for such resources to remain undeveloped once discovered. This poses peculiar problems for energy planners because, although one cannot plan on the basis of undiscovered resources, it is nevertheless necessary to recognize that a significant oil or gas discovery will require a revision of earlier plans. This is another factor which favors a flexible and diversified approach to energy supply problems.

Reviewing and Updating the Energy Plan

Energy planning is a continual and developing process. An energy balance struck at any point in time will rapidly become out of date. The previous paragraphs have outlined some of the uncertainties involved in the energy planning process, and it is therefore essential that the energy plan should be continually revised and brought into line with new developments and changes in the overall situation, both national and international.

CHAPTER III

ENERGY RESOURCE ENDOWMENT AND DEVELOPMENT CHARACTERISTICS

The present high prices of crude oil and refined products, the threat of actual or artificial shortages, and the difficulty which many developing countries encounter in paying for oil imports, are all combining to force a reassessment of the energy supply situation in these countries. This section of the paper indicates the types and nature of energy resources in developing countries, and outlines briefly the steps which need to be taken if they are to be utilized, and the order of magnitude of costs for their development.

Table III-1 gives the calorific values of fuels in common use, for comparative purposes. One kilowatt hour of electrical energy has a theoretical heat equivalent of 3,413 British Thermal Units (BTU), but, if generated in a thermal power station, requires the combustion of fuel having a calorific value of about three times this amount, depending on the overall efficiency of the power plant.

Table III-2 lists countries which are known to possess, or believed to have the potential to develop, specific energy resources. In the case of undiscovered oil and gas the exact amount of the resource is obviously unknown and one is forced to rely on indirect assessment based on geological factors. Many energy resources in developing countries have never been fully investigated and only tentative estimates of the resource potential can be made. Where a resource is known to be fully developed, as for instance hydropower in Egypt, that resource is not listed in Table III-2. The table does not show OPEC countries, although several of these are abundantly endowed with energy resources other than oil and gas. The purpose of the table is primarily to indicate the potential for further energy resource development in those countries which are in, or close to being in, a state of energy deficit. Table III-3 lists the hydropower potential of developing countries as far as it can be ascertained at present.

A. Oil and Gas

Crude oil is a mixture of liquid substances composed predominantly of carbon and hydrogen, which when distilled are separated into fractions of varying boiling point ranges, from naphtha at the light end, through kerosene, gas oils, to residual fuels at the heavy end. Naphtha is the raw material for making gasoline, and diesel fuels are obtained from the gas oil fraction. Crude oils vary widely in their content of the various boiling point fractions. Since the light fractions usually command the highest price, light crude commands a market premium over heavy crude. Impurities such as sulphur and certain heavy metals (e.g., vanadium) are usually concentrated in the residual

Table III.1: CALORIFIC VALUE OF FUELS

Fuel	BTU/pound
Crude oil	18,300-19,500
Gasoline	20,500
Kerosene	19,800
Gas oil (diesel fuel)	19,200
Ethyl alcohol (pure)	11,600
Liquefied petroleum gases (LPG)	20,500
Anthracite	13,000
Bituminous steam coal	10,200-14,600
Lignite	6,000 - 7,000
Coal briquettes	11,000-14,000
Oil shale	3,000 - 4,000
Wood (air dried) - Pine	6,000 - 9,000
- Hardwood	3,000 - 5,000
Charcoal	11,000-14,000
Peat (air dried)	6,000 - 9,000
Sugar cane bagasse (dry)	8,000 - 9,000
Corn cob	8,100
Straw (dry)	7,000 - 8,000
Dung cakes (air dried)	4,000 - 5,000
Vegetable oil	16,000-17,000
Cotton sticks	5,400
Nut shells	10,000
Solar energy	3,400 BTU per square meter per hour maximum
Natural gas	1,000 " " " " " " " 1/
Biogas	550 " " " " " " "

Note: The above values are approximate and relate to the better grades of fuel. For instance wet wood, or coal with 50% ash content, have far lower calorific values than those shown in the table.

1/ For rough comparison, 6,000 cubic feet of gas has about the same calorific value as one barrel of oil.

Table III.2: CHARACTERIZATION OF NON-OPEC DEVELOPING COUNTRIES BASED ON THEIR POTENTIAL ENERGY RESOURCES

I. Net Oil Exporters

- Angola
- Bahrain
- Bolivia
- Brunei
- Congo
- Egypt
- Malaysia
- Mexico
- Oman
- Peru
- Syrian A. R.
- Trinidad and Tobago
- Tunisia
- Zaire

II. Oil and/or Gas Producers

- Afghanistan
- Argentina
- Bangladesh
- Barbados
- Brazil
- Burma
- Cameroon
- Chile
- Colombia
- India
- Morocco
- Pakistan
- Philippines
- Thailand
- Turkey
- Yugoslavia

III. Potential Oil and/or Gas Producers

- Benin
- Chad
- Costa Rica
- Cyprus
- Dominican Republic
- Eq. Guinea
- Ethiopia
- Fiji
- Gambia
- Ghana
- Guatemala
- Guinea Bissau
- Guinea Rep.
- Guyana
- Haiti
- Honduras
- Ivory Coast
- Jamaica
- Jordan
- Kenya
- Korea
- Lebanon
- Liberia
- Mali
- Madagascar
- Mauritania
- Mauritius
- Mozambique
- Nepal
- Nicaragua
- Niger
- Panama
- Papua New Guinea
- Senegal
- Sierra Leone
- Somalia
- Sri Lanka
- Sudan
- Surinam
- Tanzania
- Togo
- Upper Volta
- Uruguay
- Vietnam
- Yemen A. R.
- Yemen, PDR

IV. Potential Geothermal Producers

- Cameroon
- Chile
- Colombia
- Costa Rica
- El Salvador
- Ethiopia
- Guatemala
- Kenya
- Malawi
- Nicaragua
- Philippines
- China, Republic
- Tanzania
- Turkey
- Uganda
- Yemen Arab Republic

V. Coal-Endowed

- Argentina
- Bangladesh
- Botswana
- Brazil
- Chile
- Colombia
- India
- Mexico
- Malagasy
- Mozambique
- Peru
- Korea, Republic
- Swaziland
- Turkey
- Vietnam
- Yugoslavia
- Zambia

VI. Indigenous Energy Resource Deficient 1/

- Cyprus
- Dominican Republic
- Gambia
- Haiti
- Jamaica
- Jordan
- Lebanon
- Mauritius
- Singapore
- Upper Volta

1/ Proven and probable indigenous commercial energy resources, which are at present competitive with imported oil, are small relative to commercial energy demand in these countries.

Table III.3: HYDROPOWER CAPACITY IN DEVELOPING COUNTRIES

Countries	Gross Theoretical Capability (TJ)*	CAPACITY (MW) Operating	Under Construction	Planned	Unused
Afghanistan	n.a.	n.a.	n.a.	n.a.	n.a.
Angola	252,002	284	80	300	9,000
Argentina	8,755,279	1,893	4,212	36,323	9,125
Bangladesh	n.a.	80	50	100	1,087
Brazil	2,399,536	15,297	24,225	16,537	44,567
Chile	805,321	1,454	950	6,595	6,781
Colombia	4,644,004	1,900	1,150	23,350	23,600
Costa Rica	802,807	214	270	1,635	4,881
Egypt	n.a.	2,445	n.a.	2,440	n.a.
El Salvador	15,120	97	135	940	n.a.
Ethiopia	819,876	n.a.	n.a.	1,390	7,602
Ghana	n.a.	948	n.a.	140	527
Guatemala	46,008	96	n.a.	1,100	n.a.
Honduras	n.a.	69	n.a.	n.a.	n.a.
India	777,602	6,750	6,800	56,450	n.a.
Ivory Coast	230,402	225	n.a.	555	n.a.
Malaysia	n.a.	296	348	341	334
Mexico	n.a.	3,885	3,030	17,975	n.a.
Mozambique	180,002	90	3,700	2,500	5,000
Pakistan	n.a.	2,173	1,125	n.a.	31,171
Peru	n.a.	1,389	n.a.	n.a.	n.a.
Philippines	70,543	641	2,085	n.a.	4,778
Rwanda	n.a.	41	n.a.	128	n.a.
Spain	557,440	11,355	2,326	8,835	6,808
Syria	n.a.	204	n.a.	n.a.	n.a.
China, Republic	105,448	1,365	27	321	n.a.
Thailand	244,113	910	780	6,573	13,602
Tunisia	69	29	n.a.	n.a.	25
Turkey	1,570,485	19,577	n.a.	n.a.	n.a.
Uruguay	n.a.	252	1,890	300	465
Yugoslavia	396,004	4,247	910	9,500	2,300
Zaire	n.a.	597	289	n.a.	32,000
Zambia	757	910	n.a.	n.a.	n.a.

* One tera joules (TJ) = 2.8×10^5 Kwh.

Source: World Energy Conference.

NA = Not available.

fuel. High concentrations of these reduce its commercial value. The grade of a crude oil is normally expressed in degrees API. Lighter crudes have higher API values. Table III-4 lists distillation fractions for some selected crude oils.

Table III.4: DISTILLATION FRACTIONS FOR VARIOUS CRUDE OILS

Crude Oil Type	API Gravity	Naphtha %	Kerosene %	Gas Oil %	Residual Fuel %	Sulphur %
Bachaquero Heavy Venezuela	17.0	2.8	7.0	31.4	58.8	2.44
Boscan Venezuela	10.3	4.0	NA	28.6	67.4	5.50
Arabian Light	33.4	17.4	15.0	19.8	46.1	1.80
Arabian Heavy	28.2	14.7	12.5	16.4	53.1	2.84
Bonny Light Nigerian	37.6	28.4	15.4	23.2	33.0	0.13
Minas Indonesia	35.8	19.5	9.0	36.5	35.0	0.08

NA = Not available.

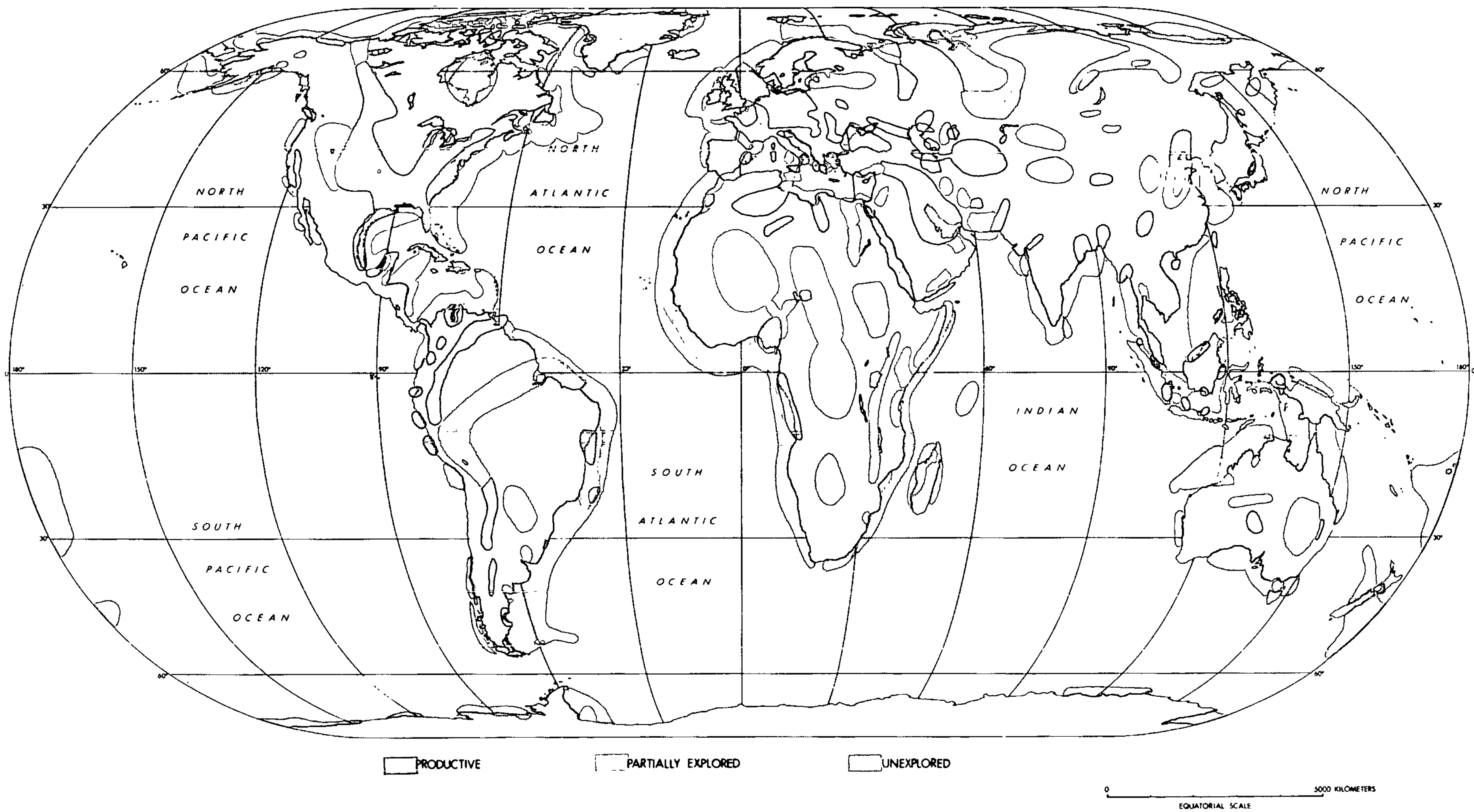
Natural gas may be almost pure methane, but also may occur mixed with noncombustible gases such as nitrogen and carbon dioxide, which may be present in such large proportions as to render the gas commercially valueless. Hydrogen sulphide is a poisonous contaminant which is often present and must be removed before natural gas can be marketed. Natural gas can occur alone in a reservoir (nonassociated) or in solution in crude oil with which it is produced (associated). "Wet gas" contains higher hydrocarbons such as propane and butane which can be separated and liquefied under pressure [liquefied petroleum gases (LPG)]. Raw gas must be dehydrated and stripped of contaminants such as hydrogen sulphide and carbon dioxide, and LPG must be removed, before it can be transported by pipeline. Associated gas may simply be burned as waste (flared) or may be stripped, compressed, and put in a pipeline for transport to market. Ethane may also be recovered from natural gas for use as a petro-chemical feedstock where a market exists.

Oil and gas are found in areas known in geological terminology as sedimentary basins. Map No. 1 shows the approximate area of the known sedimentary basins of the world, indicating which of them are currently producing oil and gas. The assumption is that if a country has a sedimentary basin in its territory there is a possibility of finding oil and gas. This assumption, while generally correct, does not hold in every case. To some extent the evaluation of the oil potential of any given area is a matter of subjective judgment by individual petroleum geologists; hence the wide diversity of estimates of undiscovered oil and gas in any particular country.

Developing countries have a large potential for oil and gas production. At present these countries (including OPEC countries) produce one-third of primary energy production and 60% of world crude oil production, and account for an even higher proportion of international trade in primary energy commodities (mainly crude oil). Non-OPEC developing countries produce about 5% of world petroleum and also produce about 5% of internationally traded crude oil, although this proportion may increase with the re-emergence of Mexico as a major oil exporter. Developing countries have considerable potential for increasing oil and gas production, but this will not take place unless the pace of exploratory activity is increased above its present levels, which are barely adequate to offset the natural decline of production from existing fields. Natural gas is an underutilized resource in developing countries, for reasons explained in Chapter IV. At the present time a very large proportion of the associated gas produced with crude oil is burned as waste (flared). The loss of energy which results is enormous, estimated to be equivalent to nine million barrels of crude oil per day in 1977. The utilization of natural gas in developing countries is expected to increase fairly rapidly in the next two decades. Table III-5 lists those non-OPEC countries considered to have some possibility of finding additional oil and gas reserves, or in the case of those where no discoveries have yet been made, where exploration may be justified. The ranking of potential is subject to the reservations discussed in the previous paragraph.

Most developing countries' sedimentary areas are relatively unexplored in comparison with those of the industrialized countries. One measure of this is the density of drilling, in terms of the number of wells drilled per thousand square kilometers of prospective area. This type of statistical analysis makes no distinction between the relative oil potential of different sedimentary basins, which covers a very wide range, and is also open to subjective judgment as to what is the size of the prospective area in any country. Nevertheless, if used with caution, it provides a useful yardstick for estimating the intensity of exploration. Table III-6 gives such an estimate, which serves to illustrate the great disparity in exploration effort between the industrialized countries and the non-OPEC developing countries in particular.

PETROLEUM BASINS OF THE WORLD



IBRD 13898R2
SEPTEMBER 1979

Table III.5: DEVELOPING COUNTRIES: POTENTIAL FOR FURTHER OIL AND GAS DISCOVERIES

	Good to Very Good	Good	Fairly Good	Fair	Poor to Moderate
South Asia					
Low Income		Bangladesh Burma India Pakistan		Sri Lanka	Nepal
East Asia and Pacific					
High Income	Brunei				
Upper Middle					Singapore Hong Kong
Intermediate Middle	Malaysia			Korea, Rep.	
Lower Middle			Papua New Guinea Philippines a/ Thailand a/		
Low Income			Vietnam		Laos
Europe, Middle East, North Africa					
High Income	Bahrain Oman				
Upper Middle		Yugoslavia			
Intermediate Middle	Syria Tunisia	Turkey			
Lower Middle	Congo Egypt	Morocco		Jordan	
Low Income		Afghanistan		Yemen AR Yemen PDR	
East Africa					
High Income					
Upper Middle Income					
Intermediate Middle					Mauritius
Lower Middle Income				Mozambique	Botswana
Low Income		Zaire	Tanzania	Ethiopia Madagascar Somalia	Comoros Islands Kenya Lesotho Malawi Uganda
West Africa					
High Income					
Upper Middle					
Intermediate Middle				Sao Tome and Principe	
Lower Middle	Angola Congo	Cameroon	Ivory Coast a/ Ghana a/ Benin	Equatorial Guinea Togo Senegal	
Low Income			Chad a/	Central Africa Empire Gambia Guinea Mali Niger Sierra Leone	Upper Volta
Latin America and Caribbean					
High Income					
Upper Middle	Mexico Trinidad and Tobago	Argentina Brazil Barbados		Surinam Uruguay Jamaica	
Intermediate Middle	Peru	Colombia	Guatemala a/	Guyana Paraguay Dominican Republic Nicaragua Costa Rica	
Lower Middle		Bolivia		Panama Honduras	
Low Income				Haiti	
Total Number of Countries	13	15	10	30	[illegible]

a/ Will join the list of oil/gas producers shortly.

Table III-6: OIL EXPLORATION DRILLING DENSITY, 1976

	Petroleum Prospective Area (Million Sq. Miles)	Drilling Density (No. of wells per thousand sq. miles of petroleum prospective area)
World 1/	30.5	109
Industrialized Countries	9.0	290
(of which US)	(3.1)	(780)
Non-OPEC Developing Countries	12.9	7
(of which Oil Importing)	(8.6)	(5)
OPEC Countries 2/	4	20

1/ Does not include centrally planned economies.

2/ The relatively low density in OPEC countries is due to the very favorable geological conditions, i.e., large individual fields, which do not apply elsewhere.

Source: Grossling

Over the past ten years, exploratory wells have been drilled in 71 non-OPEC developing countries. Another 19 have been explored by seismic surveys without drilling, and three countries by other means. The drilling density--the number of wells drilled per 1,000 square miles--is far lower than in the OPEC and the industrialized countries, and is lowest of all in the OIDCs. Such exploratory drilling as has taken place in the latter has been sporadic; in 1975-76 it amounted to about 5% of the world total and was actually lower than in 1972-73 despite a substantial increase of drilling in the industrialized countries; where the intensity was already far higher (about 90% of the world total) 1/ Over the same period there was also a decline in expenditures on geophysical work in Asia (-31%) and Africa

1/ Source: Oil and Gas Journal and International Petroleum Encyclopedia. Almost all the drilling in the industrialized countries took place in Canada and the United States.

(-12%) and only a slight increase in Latin America (4%). In the United States the increase was 60%. It appears that there was an increase in total drilling activity in most developing countries in 1978, however.

Petroleum Exploration and Development Costs

The cost of petroleum exploration is high, and is rising rapidly. Between 1970 and 1976 the cost of drilling wells in the US rose 2-1/2 times and the cost of other operations has risen in proportion. 1/ The costs of most petroleum exploration operations in developing countries are considerably higher than in the USA because of the general lack of infrastructure and support services.

Petroleum exploration normally takes place in three stages: geological and geophysical surveys, exploratory drilling, and appraisal drilling. The first stage identifies a suitable area for exploration and defines sites for exploratory wells within that area. Over 90% of all surveys for petroleum exploration are of the reflection seismic type and these therefore account for some 80% of the total cost of this preliminary stage. Table III-7 gives the costs of seismic surveys in 1977. The cost of this first stage of petroleum exploration varies widely according to the area surveyed, the type of terrain and its accessibility; a typical range of costs for such a program would be $1 million to $5 million. The time required to complete the first phase of exploration ranges from a few months for an offshore area, to as much as four years for an area of bad terrain on land. Worldwide survey activity in terms of line-miles surveyed decreased by some 50% from its peak in 1974 to end 1977 according to oil industry statistics.

Exploratory Drilling

This is commonly the most expensive part of any exploration program. Costs vary over a very wide range, depending on the depth of the well and the accessibility of the site. It is not uncommon for the access road to a remote land site to cost as much as drilling the well itself. Offshore exploratory drilling costs run anywhere from three to five times as much as an onshore well of comparable depth and drilling conditions. In general it is assumed that drilling costs make up 50% or more of total exploratory costs, but the proportion can be higher for an offshore project.

1/ Preliminary reports indicate that the cost of drilling and equipping wells in the US rose about 15% in 1978. Costs of drilling in developing countries probably rose at least as much.

Table III.7: GEOPHYSICAL SURVEY COSTS FOR PETROLEUM EXPLORATION, 1977

Area	Average miles per crew-month	Average Cost per month US$000	Average Cost per mile US$000
I. Seismic Reflection Surveys			
(a) Land Surveys			
Latin America	56	142.7	2.5
Africa	64	165.9	2.6
Middle East	44	126.7	2.9
Far East	51	101.3	2.0
(b) Marine Surveys			
Latin America	837	244.8	0.29
Africa	595	226.2	0.38
Middle East	898	246.5	0.27
Far East	714	205.5	0.29
II. Airborne Surveys 1/	4,000	100.0	0.025

1/ Extrapolated averages.

Source: Oil and Gas Journal, Geophysics.

Offshore drilling costs are greatly influenced by the depth of water at the drilling site and weather conditions. Table III-8 gives representative petroleum exploration costs, including drilling. It must be emphasized that these are only indications of orders of magnitude. Actual costs could be much greater than those shown, under adverse circumstances, but are unlikely to be much less.

Appraisal drilling involves the drilling of additional wells after a discovery has been made, for the purpose of proving the extent of the field and the amount of reserves. Depending on circumstances some three to ten appraisal wells might be drilled before a decision is taken on how to develop a field. If the appraisal wells indicate that the reserve is too small to be economic, the project may be dropped. Appraisal wells cost only about two-thirds of the cost of an exploratory well on land, but may cost the same as exploratory wells offshore. Because of the high drilling costs involved it is usual to drill fewer appraisal wells offshore than on land.

Table III.8: REPRESENTATIVE PETROLEUM EXPLORATION COSTS
(in millions of US$)

	Good Conditions	Bad Conditions
(a) On Land		
Geological and geophysical surveys	2.0- 3.0	6.0-10.0
Drill 3 wells to 10,000 feet (3,000 meters)	4.0- 5.0	10.0-15.0
Overhead, miscellaneous and contingencies	1.5- 2.0	4.5- 6.0
Total	7.5-10.0	20.5-31.0
(b) Offshore		
Geophysical surveys	1.0- 2.0	2.0- 3.0
Drill 3 wells to 10,000 feet (3,000 meters)	9.0-12.0	20.0-30.0
Overhead, miscellaneous and contingencies	3.0- 5.0	5.0-10.0
Total	13.0-19.0	27.0-43.0

The appraisal stage is an essential part of the development process since it permits the development cost and the economic viability of the project to be calculated. When completed, it permits the explorer to obtain capital for development, since the oil and gas reserve position can be determined with some confidence.

The risks of petroleum exploration are high. Only one in eight to one in thirteen exploratory wells are successful in discovering a field, depending on the area. On the whole the success ratio tends to be higher in developing countries where the drilling density is lower. Nevertheless, an area can go through two or three phases of exploratory activity over a period of 20 years without any commercial accumulations of oil or gas being found. The risk in drilling appraisal wells is less than for exploratory (wildcat) wells, about one in two being dry on the average.

Petroleum development costs commonly represent about 70% of the total investment involved in finding and in developing a new oil field. However, conditions vary so widely from one area to another, depending on the existence of transport infrastructure such as roads, pipelines, loading terminals, refineries, etc., that it is difficult to give precise representative figures. As a general rule of thumb it is accepted that, outside the OPEC countries, development costs for new production onshore will be of the order of $8,000 to $10,000 per daily barrel of production, while offshore the cost will be in the range of $15,000 to $20,000 per daily barrel. Thus an onshore oil field having a daily production of 30,000 barrels per day would cost about $300 million to develop. Because offshore costs are generally so much higher than onshore costs, the minimum size of field that is economic to develop is considerably larger than on land. Gas fields generally cost appreciably less to develop than an equivalent oil field because fewer wells are required to attain an acceptable recovery of gas from the reservoir.

B. Coal

Coal is a solid fuel consisting predominantly of carbon, but containing in most cases substantial quantities of volatile matter, moisture, and mineral ash, and usually a minor percentage of sulphur. Coal occurs in layers, variously known as beds, or seams. The layers may be only a few inches thick, up to 20 or 30 feet, or even more in some cases. The range for mineable coal is usually between two and ten feet thick. There are an infinite number of variations in the grade and composition of coals, depending on geological circumstances, but they are generally classified by their heating value (calorific value) expressed in British Thermal Units per pound (BTU/lb) or kilocalories per kilogram (Kcal/kg). The principal use for coal is as a boiler fuel, with the exception of metallurgical grade coking coal which is used as a chemical reagent in the smelting of iron ore. Coal can also be used as a domestic fuel, particularly if it is processed to make smokeless fuel.

The World Energy Conference in 1977 showed economically and technically recoverable coal reserves in the world to be 636 billion metric tons, of which only 10% is located in developing countries. Total known coal resources in the developing countries are reported to be 230 billion tons. A larger proportion of these reserves may be recoverable in the future than is estimated at present. India, Swaziland, Botswana, Indonesia, and Brazil account for more than 60% of presently recoverable coal reserves in developing countries. Table III-9 lists coal reserves in developing countries. In many countries the full extent of coal resources has never been determined, and evaluating these should receive high priority in those countries where coal is known to exist.

Table III.9: COAL RESERVES AND RESOURCES OF DEVELOPING COUNTRIES

	Geological Resources		Technically and Economically Recoverable Reserves		Degree of Exploration
	Million tce	%	Million tce	%	
DEVELOPING COUNTRIES					
Africa					
Botswana	100,000	0.99	3,500	0.55	L-M
Mozambique	400	--	80	0.01	M
Nigeria	180	--	90	0.01	M
Rhodesia	7,130	0.07	755	0.12	M
Swaziland	5,000	0.05	1,820	0.29	M
Zambia	228	--	5	--	L-M
Algeria	20				L
Angola	500				L
Benin	n.a				L
Burundi	n.a				L
Cameroon	500				M
Egypt	80				M
Ethiopia	n.a				L
Madagascar	92	0.02		0.15	M
Malawi	14				M
Niger	n.a				L
Morocco	96				M
Sierra Leone	n.a				L
Somalia	n.a				L
Tanzania	360				M
Tunisia	n.a				L
Zaire	73				L
Total Africa	115,338	1.14	7,220	1.13	
Asia					
Bangladesh	1,649	0.02	519	0.08	
India	56,799	0.56	33,700	5.30	M-H
Indonesia	3,723	0.04	1,430	0.22	L
Iran	385	--	193	0.03	M
Korea, Republic	921	0.01	386	0.06	M
Turkey	3,268	0.03	793	0.12	M
Afghanistan	85	--	--	--	L
Burma	286	--	--	--	M
Brunei	1	--	--	--	L
Cambodia	n.a	0.06	n.a	0.25	L
Pakistan	1,375	--	--	--	M
Philippines	87	--	--	--	L-M
China, Republic	680	--	--	--	M
Thailand	78	--	--	--	M
Viet-Nam	3,000	--	--	--	M
Total Asia	72,466	0.72	38,583	6.06	
Latin America					
Argentina	384	--	290	0.05	L
Brazil	10,082	0.10	8,098	1.27	L-M
Chile	4,585	0.05	162	0.03	M
Colombia	8,318	0.08	443	0.07	L
Mexico	5,448	0.05	875	0.14	M
Peru	1,122	0.01	105	0.02	M
Venezuela	1,630	0.02	978	0.15	M
Bolivia	n.a				M
Costa Rica	n.a				L
Ecuador	22				M
Guatemala	n.a	..	n.a	..	L
Honduras	n.a				L
Panama	n.a				L
Total Latin America	31,692	0.31	10,951	1.73	
Europe					
Yugoslavia	10,927	0.11	8,465	1.33	H
TOTAL DEVELOPING COUNTRIES	230,360	2.28 (% of world resources)	65,219	10.25 (% of world recoverable reserves)	

.. negligible, less than 0.01%
n.a. = not available

Degree of Exploration: H = well established reserve estimates, well-defined geology within each coal-bearing
M = some exploration programs have been documented
L = few exploratory programs

tce = metric tons of coal equivalent.

Source: World Energy Conference, 1977; "World Coal Supply Forecast", Skelly & Loy, Harrisburg, Pennsylvania, for the World Bank, December 1978.

World coal production in 1977 was 2,774 million tons, equivalent to about half the energy equivalent of oil output. Of this total 176 million tons were mined in developing countries. Ten of these, namely Yugoslavia, Republic of Korea, Turkey, Pakistan, Republic of China, Vietnam, Brazil, Chile, Colombia, and Mexico between them account for 96% of this total. Table III-10 shows actual and forecast coal production in developing countries. It is evident that there is considerable scope for increasing production of coal in developing countries, since 21 of them are reported to have economically recoverable reserves and some 40 countries are reported to have deposits of coal.

Coal production costs vary over a wide range, but open-cast mining is invariably much cheaper than underground mining. Low-grade coals often cannot be exploited economically except by the open-cast method. Mining costs on a worldwide basis in 1978 averaged $10-15 per ton for open-cast mines, and $20-30 per ton for underground mines. For a good grade of steam coal, this would compare with a cost of $14-20 per ton of fuel oil equivalent for open-cast coal and $27-40 per ton of fuel oil equivalent for coal from underground mines. Ex-refinery prices for Bunker C fuel oil (heavy fuel oil) in July 1979 were quoted as being in the range of $100-130 per ton on the international market. Cost for coal transport by rail might be of the order of $0.02-0.03 per ton-mile. Even allowing for the higher cost of transporting and using coal as compared with fuel oil, and the fact that many coal deposits in developing countries are of inferior grade, such a price differential would appear to give ample incentive for accelerated development of indigenous coal resources in developing countries.

Capital requirements for coal development range from $10,000 to $35,000 per daily ton, open-cast mines being at the lower end of the range and underground mines at the upper end. In terms of calorific value of the output, this equates to some 20% to 50% of the estimated cost of new oil development. To this, however, must be added the cost of transport facilities from the mine to market, which obviously depends on the distance and type of terrain involved. As a very rough guide, capital costs for railroad construction are likely to be of the order of $100,000 to $150,000 per mile for fixed equipment and from $500,000 up to several million dollars per mile for civil engineering construction. In general it would not be worth building a railroad for traffic of less than 500,000 tons per year, so that for small mines road transport would have to be used.

Exploration for coal is less costly than for oil, but nevertheless represents a risk outlay. It is carried out by means of geological surveys, assisted by geophysical methods and drilling to prove the thickness, continuity and grade of the coal away from the outcrop. Before developing a modern mine it is necessary to confirm the availability of sufficient reserves to justify the capital outlay. This is done by the same means as

Table III-10: COAL PRODUCTION PROSPECTS OF DEVELOPING COUNTRIES

	Recoverable Reserves 1/ Million tce	Production Million tce				Annual Growth Rate (%)	
		1977	1980	1985	1990	1977-85	1985-90
DEVELOPED MARKET ECONOMIES	324,341	1,234.6	1,265	1,476	1,752	3.3	3.5
CENTRALLY PLANNED ECONOMIES	246,304	1,463.4	1,662	2,089	2,610	4.6	4.5
DEVELOPING COUNTRIES							
Africa							
Botswana	3,500	0.2	0.2	0.3	3.0	5.2	75.5
Morocco	(96)	0.6	0.9	1.0	1.1	6.6	1.9
Mozambique	80	0.4	1.0	2.0	3.0	22.3	9.45
Nigeria	90	0.3	0.3	1.0	3.0	16.2	24.6
Rhodesia	755	2.5	4.0	4.6	5.2	7.9	2.5
Swaziland	1,820	0.1	0.5	1.5	5.0	28.6	27.2
Zaire	(73)	0.1	0.1	0.1	0.1	0.0	0.0
Zambia	5	0.8	1.3	1.9	2.5	11.4	5.6
Tanzania	(360)	2/	2/	2.0	3.0	-	8.5
Burundi	n.a.	2/	2/	2/	2/	-	-
Algeria	(20)	2/	2/	2/	2/	-	-
Angola	(500)	-	-	-	2.0	-	-
Cameroon	(500)	-	-	-	-	-	-
Benin	n.a.	-	-	-	-	-	-
Egypt	(80)	-	-	-	-	-	-
Ethiopia	n.a.	-	-	-	-	-	-
Madagascar	(92)	-	-	1.0	2.0	-	-
Malawi	(14)	-	-	-	-	-	-
Niger	n.a.	-	-	-	-	-	-
Sierra Leone	n.a.	-	-	-	-	-	-
Somali	n.a.	-	-	-	-	-	-
Tunisia	n.a.	-	-	-	-	-	-
Total Africa	7,220	5.0	8.3	15.4	31.9	14.8	17.1
Asia							
Afghanistan	(85)	0.2	0.2	0.6	1.6	14.7	20.1
India	33,700	99.7	125.0	145.0	190.0	4.8	5.6
Indonesia	1,430	0.2	0.2	3.5	12.0	42.2	27.4
Iran	193	0.9	1.0	1.5	1.5	6.6	0.0
Pakistan	(1,375)	1.0	1.5	2.0	3.0	9.1	8.5
Philippines	(87)	0.3	0.3	1.6	4.0	23.3	20.1
Korea, Rep.	386	18.3	19.0	22.0	25.0	3.1	2.6
China, Rep.	(680)	2.9	4.0	5.0	6.0	5.7	4.5
Turkey	793	7.4	9.8	13.0	16.2	7.3	5.9
Viet Nam	(3,000)	6.0	10.0	15.0	20.0	12.1	24.6
Thailand	(78)	0.2	0.5	2.0	6.0	33.4	-
Burma	(280)	2/	2/	2/	2/	-	-
Bangladesh	519	-	-	-	2.0	-	-
Brunei	(1)	-	-	-	-	-	-
Malaysia	(75)	-	-	-	2.0	-	-
Laos	n.a.	-	-	-	-	-	-
Total Asia	38,583	136.1	171.5	211.2	288.7	5.7	6.3
Latin America							
Argentina	290	0.5	2.3	3.5	7.5	27.5	16.5
Brazil	8,098	3.5	6.4	10.0	20.0	13.9	14.9
Chile	162	1.2	2.0	2.5	7.5	9.6	24.6
Colombia	443	3.7	5.0	10.0	20.0	13.2	14.9
Mexico	875	6.0	6.7	8.0	9.3	3.7	3.1
Peru	105	2/	0.2	0.3	0.4	*	5.9
Venezuela	978	0.1	1.2	5.0	8.8	63.1	12.0
Bolivia	n.a.	-	-	-	-	-	-
Haiti	(7)	-	-	-	0.3	-	-
Ecuador	(22)	-	-	-	-	-	-
Guatemala	n.a.	-	-	-	-	-	-
Honduras	(0.2)	-	-	-	-	-	-
Panama	n.a.	-	-	-	-	-	-
Total Latin America	10,951	15.0	23.8	39.3	73.8	12.6	13.4
Europe							
Yugoslavia	8,463	19.8	29.5	38.2	46.0	9.3	3.8
TOTAL DEVELOPING COUNTRIES	61,219	175.9	233.1	304.1	440.4	7.1	7.6
GRAND TOTAL	634,364	2,773.7	3,160.1	3,869.1	4,802.4	4.2	4.4

* Annual growth rate in excess of 50% due to very low 1977 production base; n.a. - not available.
1/ Figures in parenthesis represent "geological resources," since no "reserve" data available.
2/ Output below 0.1 million tce in 1977.
Sources: Reserves: World Energy Conference, 1977 → Skelly & Loy; 1977 Production - USBM, United Nations Energy Statistics; Supply Forecasts: Skelly & Loy World Bank Projections

t.c.e.: metric tons of coal equivalent.
n.a.: not available.

in exploration, but with much closer spacing of the drill holes. These are usually arranged on a grid pattern and cores are taken from the coal beds for analysis of the quality of the coal. Since drill holes for coal are relatively shallow compared with oil and gas wells (2,000 feet maximum) the equipment required is much lighter and less costly than that used in oil exploration. Nevertheless, a program of coal exploration followed up by drilling to prove reserves for a mine or mines can cost from $2 to $20 million, depending on the area to be explored and the depth of the coal beds. Before opening a large new mine it is usual to obtain bulk samples, of the order of several tons or more, for testing the properties of the coal and the possibility of improving the coal by washing.

Coal analyses usually record the following information: calorific value, ash content, fixed carbon, volatile matter, sulphur content, and moisture. Some analyses are quoted on the basis of dry ash-free coal, which can be very misleading if the basis of the analysis is not stated. Since any particular coal bed can vary widely in both thickness and properties, a thorough evaluation for planning a mine requires a considerable number of sampling points and analyses.

Certain types of bituminous coal can be made into coke by heating in the absence of air (being carbonized). Coke is a hard, brittle, porous substance widely used in the smelting of iron ore, and metallurgical grade coking coal remained an export commodity even through the era of cheap oil prices. Few developing countries possess good quality coking coals, which therefore have to be imported if an iron and steel industry is set up. Some of the coals found in developing countries have weak coking properties but can be used for metallurgical purposes if blended with higher quality imported coking coal.

Manpower requirements for coal mining are considerably higher than for oil production, and underground mining is considerably more labor intensive than open-pit mining. Even in the case of underground mining it is possible to opt for a capital-intensive mechanized mining system (if geological conditions are appropriate) or for a labor-intensive system. Productivity per man-shift therefore varies over a wide range. Productivity in a nonmechanized labor-intensive mine would be of the order of 1/3 to 1/2 ton per man-shift; in a mechanized mine in Europe it is 3 to 5 tons per man-shift, and for an open-pit mine it should be in the range of 20 to 60 tons per man-shift. The average size of underground mine in LDCs is still small, in the range of 100-500 tons of output per day, although there are some much larger mines in India, for example. Open-cut mines are usually more modern and have a much higher output, in the range of 3,000 to 10,000 tons per day.

Training for miners is an important element in any scheme to develop indigenous coal resources, especially in countries with no previous history of mining. Underground coal mining is difficult and dangerous work, and the use of poorly trained or unskilled labor may result in serious damage or even total loss of the mine, not to mention the loss of life involved.

C. Oil Shale

Oil shale is the name given to a group of rocks which may, or may not, be shales, and which do not contain free oil. They are fine-grained bedded rocks ranging from shale through calcareous shale to impure limestone. They contain complex organic substances which, on being heated to above 600 degrees Celsius, break down to yield a mixture of oils resembling crude oil, which can be refined in the same way as crude oil to yield gasoline, diesel fuel, and fuel oil. At higher temperatures increasing proportions of gas are formed. The richer shales yield 30 to 40 US gallons of oil, and sometimes more, per ton of shale, but the majority of deposits are leaner than this. There is no lower limit in physical terms, and in estimating reserves some arbitrary cut-off point such as 15 gallons of oil per ton is used, based on assumptions as to what may be economic to develop at some future date.

World reserves of oil shales are very large. The US Geological Survey has estimated that known reserves of shale yielding more than 10 gallons of oil per ton amount to the equivalent of 100 billion barrels of oil in Africa, 104 billion barrels in Asia, and 800 billion barrels in South America. Potential, but as yet unproven, reserves are much greater still. Countries known to have significant oil shale resources are Zaire, Morocco, Canada, USA, Brazil, Thailand, Italy, Sweden, USSR, and China. Many other countries have smaller but nevertheless potentially exploitable deposits, e.g., UK, France, Israel, Jordan, Turkey and Burma.

Oil is extracted from the shale by mining, crushing and heating it in retorts. More recently techniques have been developed for retorting the shale in underground chambers. The oil shale industry has a history of more than 100 years and it is estimated that about 400 million barrels of oil had been extracted from shale up to 1961. At the present time the only active industries are in the USSR (Lithuania) and China. Pilot plants have been operated in both the US and Brazil, and it is reported that full-scale extraction plants will soon be built in both countries. Morocco and Israel are also reported to be contemplating oil shale development. The cost of oil from shale is close to the current price of crude oil according to published estimates. Significant factors in evaluating any project are the grade of the shale, thickness of the beds, cost of mining and retorting, and disposal of burned shale. Investment costs in the US are reported to be about $2 billion for a plant to produce 120,000 barrels of oil per day.

Oil shale can be burned directly as a low-grade fuel for power generation in specially constructed boilers. Shale suitable for such use has a calorific value in the range of 1,000 to 2,000 BTU/lb. If the kerogen content is too low unstable combustion results. Shale is burned as fuel in power stations in the USSR, and there is a power station in Turkey operating on a mixture of lignite and oil shale. It is reported that an oil shale-fired power plant will be built in Morocco. Ash disposal is a problem in shale-fired plants since it constitutes about 80% of the raw shale, and is usually very alkaline after being burned.

Oil shales are often not readily recognizable in the field unless they are exposed at the surface and are sufficiently rich to burn when ignited. It is, therefore, likely that many developing countries have unrecognized oil shale deposits which have been penetrated by oil wells or deep water wells without being recognized. The only definitive test for oil shales at present is to subject a sample to a Fischer Assay distillation test and measure the quantity of oil produced. Where geological conditions for oil shale occurrence are appropriate, a systematic testing program would appear to be justified.

D. Tar Sands

Tar sands are sandy rocks saturated with heavy viscous asphaltic oil. They occur in a number of countries but the largest deposits are in Canada and Venezuela. Other countries known to have tar sand deposits are the USA, USSR, Romania, Albania, Syria, Ivory Coast, Ghana, Malagasy, Trinidad, Ecuador, and Peru. Most of the deposits have never been fully evaluated and total reserves are not known precisely, but are very large. Known reserves are estimated to contain some 1,500 million barrels of oil in place, but the total may be larger. The oil content ranges from 10% to 18% by weight of the rock. The oil can be extracted either by solvents or hot water. The oil as extracted is heavy and very viscous and is usually refined on site before being transported to market. There are also many deposits of bitumen-saturated limestone, but because of the hardness of the rock economic extraction of the oil has not so far been feasible.

The only commercial exploitation of tar sands at the present time is in western Canada, where the sand is mined by open-pit methods and the oil extracted and refined at the site. There are plans in both Canada and Venezuela to extract oil from tar sands underground by drilling wells into the reservoirs and injecting steam. This is already done in California (USA). The cost of oil extraction from tar sands is high; in western Canada it is estimated that investment is of the order of $30,000 per daily barrel, so that a plant producing 100,000 barrels of oil per day would cost some $3 billion. It seems likely that less costly plants could be constructed in the developing countries where climatic conditions are less severe and the operational parameters are different from those in western Canada. Thus countries which possess tar sand deposits, but have insufficient conventional oil resources, would be justified in reevaluating the possibility of producing petroleum fuels from them.

E. Peat

Peat is decayed fibrous vegetable matter which has accumulated in swampy areas, often to thicknesses measured in tens of feet. As found, peat is usually saturated with water and will not burn. However, after excavating and air drying for several days or weeks (depending on the climate) it dries out to less than 30% moisture and has a calorific value of 6,000 to 9,000 BTU/lb, in the same range as dry wood. It is normally a light fibrous material, which can be burned for steam raising on an industrial scale in specially designed boilers, and has been used for power generation in the USSR, Germany, Finland, and Ireland. Peat can also be compressed in briquettes for use as a domestic fuel.

There is considerable evidence that peat may be fairly widely distributed in developing countries, although so little attention has been paid to it outside the northern countries that there is little quantitative information on possible reserves. Exploitable deposits are known to exist in Belize, Cuba, Jamaica, Chile, Rwanda, and Burundi. Systematic exploration of swampy areas for peat would probably discover many more deposits. Such exploration is relatively simple and consists largely of systematic sampling of near surface material by means of hand augers or pits and trenches.

Peat exploitation generally requires low investment and is labor intensive, and so well suited to provide employment in rural areas. Developing countries lacking the more usual types of mineral fuels would appear to be justified in undertaking a systematic search for this resource.

F. Uranium

Uranium minerals are fairly widely distributed but are rarely found in high concentrations. More often they occur as accessory minerals (e.g., in the gold mines of South Africa). Uranium also shows an affinity for certain organic rocks such as oil shales and phosphate deposits (Sweden, Morocco) from which they can be extracted in the course of processing. Table III-11 lists the known uranium reserves of developing countries.

Uranium should in most cases be regarded as a strategic mineral rather than as a direct primary energy resource, since there are very few developing countries which have the capability for processing uranium into nuclear reactor fuel rods, or which could absorb a nuclear generation plant of conventional size in their overall electrical power system.

Table III.11: URANIUM RESOURCES IN DEVELOPING COUNTRIES

(1,000 tonnes U)

	\$80/kg U (\$30/lb U_3O_8)		\$80-130/kg U (\$30/lb U_3O_8)	
Cost Range	Reasonably Assured Reserves	Estimated Additional	Reasonably Assured Reserves	Estimated Additional
Algeria	28.	50	0	0
Argentina	17.8	0	24	0
Bolivia	0	0	0	0.5
Brazil	18.2	8.2	0	0
Central African Empire	8	8	0	0
Chile	0	5.1	0	0
Gabon	20	5	0	5
India	29.8	23.7	0	0
Korea, Republic	0	0	3	0
Madagascar	0	0	0	2.0
Mexico	4.7	2.4	0	0
Niger	160	53	0	0
Philippines	0.3	0	0	0
Somalia	0	0	6.2	3.4
Turkey	4.1	0	0	0
Yugoslavia	4.5	5.0	2.0	0
Zaire	1.8	1.7	0	0
Total Developing Countries	297.2	162.1	35.4	26.4
% of World Total	18.0	10.7	6.6	4.5
World Total	1,650	1,510	540	590

1/ As of 1st of January 1977.

Source: International Atomic Energy Agency.

G. Hydropower

This is one of the earliest forms of primary energy to be exploited, and simple primitive water wheels may still be found in many countries. As a result of the rise in oil prices there has been a recurrence of interest in small hydro plants (microhydro, minihydro are terms generally applied to installations having less than 1 megawatt of installed capacity) for supplying small isolated systems which formerly might have been supplied by a diesel-electric generator. Modern hydroelectric installations have installed capacities in the range of hundreds or thousands of megawatts. The largest hydro plant in the world at present is under construction at Itaipu in Brazil and will have an installed capacity of 14,000 MW.

Almost all hydro plants require some form of civil engineering works to provide water storage in order to increase the availability of energy throughout the year. The cost of these works constitutes the largest part of the investment and in most cases they must be constructed in their entirety before any energy can be generated. Hydro development is therefore characterized by high initial investment and low running costs. Many hydro installations are dual purpose, providing both power and irrigation water. Capital costs for hydropower installations vary widely. Representative capital costs, including an allowance for transmission and distribution facilities, range from \$850/kilowatt installed for a high-head 1/ installation in Colombia to \$2,500/kw for small installations in Africa. An average cost for developing countries is \$1,296/kw of installed generating capacity.

The potential for increasing hydropower output in many developing countries is considerable. For example, Africa is estimated to have 22% of world hydropower resources, but only 2% of this has been developed. One problem is that many sites have a potential far in excess of any local market demand for the energy, so that the cost per unit of energy delivered becomes prohibitively high. One solution to this problem is to locate energy-intensive industries, such as aluminum smelters, near the hydro site, as was done with the Volta River development scheme in Ghana. Another is to arrange to export the power to neighboring countries where demand is greater, as was done in the case of Uganda and Kenya.

Many developing countries have potential hydropower resources which cannot be developed at the present time because of lack of surveys. It is necessary to accumulate data on stream flow over a period of several years, and on the size of the various catchment areas so that estimates of seasonal variations and of possible variations over longer meteorological cycles can be prepared. Geological investigation of potential dam sites is also neces-

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1/ The hydraulic head is the height of the usefully available column of water above the turbine inlet, which determines water pressure at the turbine.

sary. These data will influence planning decisions on which site to select for development and the amount of reservoir storage that is needed to ensure the minimum desired firm generating capacity. If there are extreme variations in stream flow with time, or competing demands for water for irrigation, it may be necessary to plan for alternative generating facilities which can meet expected power demand during dry periods. Such feasibility studies represent only about 1% of final project investment. Substantial long-term savings are possible by undertaking such surveys and feasibility studies well before the need for new generating capacity arises. These surveys and studies form an important part of the overall national energy resource inventory needed for energy planning.

The sediment load carried by a river is another important factor which is frequently unknown in developing countries. It has an important bearing on the life of any hydroelectric storage reservoir, and is greatly affected by agricultural and other developments upstream from the reservoir. Poor agricultural practices in the catchment area and deforestation of the watersheds can enormously increase the sediment load carried by a river, and thus reduce the expected life of a downstream storage reservoir.

Many rivers form international boundaries, and development of their hydroelectric potential requires agreement between the riparian states for sharing both the power generated and the amount of water available for irrigation, if this is part of the project. An example is the Itaipu project on the Parana River between Brazil and Paraguay. The Usumacintha River which forms the boundary between Mexico and Guatemala is another example of a river whose potential cannot be developed without an agreement between the two countries. Thailand has similar problems. In some cases upstream or downstream countries have, or claim to have, rights to the water. Examples are the Aswan High Dam on the River Nile in Egypt, where the reservoir formed by the dam inundated Sudanese territory, and the dams on the Tigris River in Turkey and the Euphrates River in Syria, in both of which cases Iraq was concerned at the possible loss of water for irrigation downstream.

Many hydroelectric projects are multipurpose, being built for flood control and irrigation as much as for power. In such a case, it is sometimes a complex problem to determine which use takes priority and which should bear the principal cost of the project. It should be part of the national economic plan to determine such priorities.

There has been much discussion of microhydropower projects 1/ as a possible source of power in rural areas. However, it is frequently overlooked that these also need stream flow and site information, and careful

1/ See Staff Working Paper 346 for further discussion on this.

planning, if they are to be effective and to produce energy at a cost which local residents can afford. Apart from the cost of the turbine and generator, such installations often need a considerable amount of engineering and construction work before they can be installed, in order to ensure their proper functioning and to protect them from floods. One approach to reducing costs and promoting implementation might be to attempt some degree of standardization and modular design in manufacturing and construction.

H. Geothermal Energy

Geothermal resources consist of underground aquifers containing superheated water and steam at temperatures up to 250° Celsius, which are exploited by means of wells. Superheated water and steam from geothermal sources have been used for electric power generation, industrial process heat, and space heating. Geothermal hot water resources can also be used for domestic space heating and hot water supply.

Geothermal resources have been used in Iceland and New Zealand for industrial process steam; in Italy, Indonesia, Japan, USA, New Zealand, the Philippines, Mexico and El Salvador for electricity generation; and in Iceland for space heating and domestic hot water supply. A geothermal power plant usually produces power at lower cost than regular thermal plants because there is no direct fuel cost. However, there are appreciable exploration and production costs and sometimes problems with the disposal of waste water.

The following developing countries are believed to have geothermal potential:

Mexico	Venezuela	Turkey	Yemen A.R.	Rwanda	Martinique
Guatemala	Bolivia	Iran	Ethiopia	Burundi	Guadeloupe
El Salvador	Chile	India	Kenya	St. Lucia	Solomon Islands
Nicaragua	Argentina	Indonesia	Tanzania	Dominica	
	Costa Rica	Philippines	Cameroon		

The geothermal resources of endowed countries should be evaluated and developed because baseload electricity generated from high temperature geothermal resources is likely to be substantially cheaper than electricity produced from fossil fuels. It is important to note that the exploration and development of high temperature geothermal resources involve an element of financial risk.

Geothermal Development

Development of geothermal resources requires technology and equipment similar to that used in oil and gas exploration, but on a less costly scale. Furthermore, like oil and gas exploration, geothermal exploration is a relatively high-risk activity. Geochemical investigations and electrical resistivity surveys are used to determine the sites of initial exploratory wells. Typical expenditure for detailed surface investigations of a prospecting area of several tens of square kilometers may amount to $100,000. Exploratory wells cost about $1 million and development wells half that sum. The average depth of geothermal wells is in the range of 2,000 to 4,000 feet, but deeper wells may be used in future as the economic attractions of geothermal development increase. The cost of installed geothermal electric generating capacity is estimated to be about $1,700/kw. The cost of steam is a function of the cost of all wells drilled to obtain the required quantity of steam, and of the surface facilities, such as steam/water separators and steam pipelines. The capital cost is about $100 to $300/kw for steam production. Based on the existing plants in operation, total generating costs (steam charges plus fixed charges) will be about 3 to 5 cents per kwh for geothermal-generated electricity when the plant is used for baseload operations with a load factor of 0.8. Geothermal development costs have suffered the same cost escalation in recent years as other energy development activities, and historical costs are no longer relevant.

The area of an average geothermal field is several square kilometers, and its power potential is usually in the range of 100 to 400 megawatts. Steam produced is low pressure, in the range of 30 to 70 pounds per square inch. The life of a field under exploitation is not known for certain, but seems likely to be at least 50 years, if not more. There is still considerable discussion as to whether or not geothermal reservoirs are recharged naturally, and knowledge of the behavior of geothermal reservoirs is still limited.

Depending upon the cost of steam supplies and of transmission to consuming centers, and the difficulty of exploration and development, geothermal power may be less expensive than electricity generated by fossil fuel power plants and is an option worth considering in countries that have the potential. One advantage of geothermal development is that, once a field has been discovered, development can proceed by stages as demand increases. This is in marked contrast to hydro, where the full cost of civil engineering works must be met before any power can be developed.

CHAPTER IV

POLICY ISSUES IN FOSSIL FUEL DEVELOPMENT

In Chapter II it was shown that many developing countries have potential for increasing their output of indigenous fuels and so reducing their dependence on imported energy supplies. The increases in the international price of crude oil which have occurred since 1973 have emphasized the need for development of these resources, since imported oil now represents a large portion of total import costs in many countries. However, precisely because crude oil prices have risen so sharply, it has now become economically attractive to develop indigenous energy resources which formerly were noncompetitive with imported oil.

Policy issues associated with the development of fossil fuels fall under four broad headings:

(a) Legislation and administration
(b) Financial and fiscal
(c) Technical
(d) Environmental and social.

In the majority of developing countries, minerals are regarded as the property of the state, but the state may adopt a number of expedients to permit the development of these resources. Among those most commonly found are the following:

(a) Exploitation by a state monopoly enterprise which may, or may not, act in association with private partners;

(b) A mixed system whereby a state enterprise operates parallel with and in competition with the private sector. In such cases it is not unusual to find governments providing fiscal incentives or preferential treatment to those private enterprises which voluntarily cooperate with the state enterprise;

(c) Development entirely by the private sector, with government action restricted to overall regulation and supervision of the industry. The state does not participate actively in the development process.

State participation in mineral development generally increased in the 1950s and 1960s, but more recently this trend has been reversed as governments in developing countries have come to realize the magnitude and complexity of the task of developing energy resources single handed, and the heavy demands this makes on capital and technical expertise. Most countries now have some sort of mixed system: while it is felt that energy development is too important to be left entirely to the private sector, some private, and often foreign, capital and skills are needed to undertake the risky and expensive exploration process, especially in the case of oil and gas. The policy issue, therefore, is how, and to what extent, the state and private interests can cooperate.

Energy resource development generally requires heavy capital investment in the early stages, often of the order of $100 million or more, and lead times of five to ten years before any revenue is generated. There is also apt to be a considerable risk of loss and failure in the initial exploratory phase, particularly for oil and gas, but to some degree in all the fossil fuel industries. As a result of these characteristics, it is not unusual to find a special fiscal regime for the fossil fuel industries. This provides for favorable treatment of losses, which can usually be offset by gains for a much longer period than is usual in manufacturing industry, and there is also often a provision for accelerated depreciation of fixed assets against revenue, and a different tax law. The effect of such provisions is that the state forgoes revenue in the early years of production, until the developer has recovered his investment, in return for a larger share of revenue in the later years. The logic of this system is that the state can afford to take a longer view of the development process than can a corporate developer, whether the latter is state-or privately-owned. The state also obtains indirect benefits from the development of indigenous resources, apart from tax revenues.

A government which wishes to develop fossil fuel resources must obviously provide a suitable legislative framework; it is also highly desirable to provide a regulatory and monitoring system within which the industries can operate. This regulatory system derives its authority from the appropriate legislation, but it is preferable to allow it to be modified without having to go through the legislative process, since in many cases it will relate to technology which can change quite rapidly with time. The functions of the administrative system are to control safety, good working practices, avoidance of unnecessary waste or damage to the deposit or to other aspects of the economy, such as agriculture, forestry, or fishing. It is also part of the administrative function to verify production reports for taxation purposes. It is better that the regulatory agency should be entirely separate from any parastatal corporation set up to develop an energy resource, since if these functions are combined, abuses inevitably occur. While the regulations can be and must of necessity be modified fairly frequently, it is undesirable that the basic legislation should be subject to constant revision and amendment, since the resultant uncertainty is a great impediment to orderly development. This issue is discussed further below.

Technical aspects of fossil fuel development which call for policy decisions relate mainly to resources which must be mined, such as coal, oil shale, tar sands, or uranium. One example of such a policy decision is the choice between a labor-intensive or a capital-intensive mining system. (The oil and gas industry is by its very nature capital intensive and the question therefore does not arise in this case.) The choice between labor-intensive and capital-intensive mining systems requires consideration of the type and nature of the workforce available, the availability of capital, and the relative desirability of providing low-paid employment to a large number of people or highly-paid employment to a few. In a developing country the problems associated with capital-intensive mining systems are lack of capital, the difficulties of maintaining complicated machinery, and in many cases the need for a relatively large number of expatriate staff to operate the system. Offsetting this is the higher output and revenue of an efficiently operated capital-intensive plant. After evaluating these factors some governments have deliberately opted for a labor-intensive system in order to create the maximum employment for a relatively unskilled labor force. This also tends to avoid the problems caused by the existence of a small highly-paid elite work force in the midst of general underemployment, which may easily occur in the case of a capital-intensive system. There is no general solution to this problem and each case must be considered on its merits.

Policy issues related to technology can also arise from the need of the fossil fuel industries, particularly the oil industry, to carry out airborne surveys, including taking aerial photographs, and to operate transport and communications systems in remote areas. These are often seen as infringing on national security, or on a state monopoly in transport or telecommunications. Failure to make adequate provision for these requirements, one way or another, can seriously impede the development process.

While there is a tendency in the developing countries to regard environmental considerations as irrelevant, they can be extremely important. Unrestricted burning of raw coal and lignite in large urban areas leads to severe atmospheric pollution with a corresponding increase in respiratory disease and accelerated decay of buildings and other structures. Unrestricted surface mining can destroy the local drainage pattern and cause accelerated soil erosion, leading in turn to damage to reservoirs, river channels, irrigation systems, and agricultural land. Underground mining on a large scale can cause severe chemical pollution of surface water by water seeping from dumps or pumped from the mine, which may seriously affect river fishing and irrigation, on which a rural population may depend for subsistence. Inadequately supervised dumping of salt water and other liquid wastes by the oil industry can result in contamination of both ground and surface water with salt, to the extent that it becomes unusable. This is particularly serious in arid or semi-arid climates where the local population may be threatened by such contamination. Offshore oil operations in areas of restricted water circulation can cause severe damage to fisheries if concentrated brines or drilling fluids are dumped in the surrounding water. These problems can be especially severe where a state-owned monopoly enterprise is also the regulatory authority, since in such a case there is no external control or monitoring.

Social considerations requiring policy decisions occur at both the national and local level. At the national level, a series of oil discoveries in a country which formerly depended largely on subsistence agriculture will have far-reaching effects. The most immediate is a rapid rise in government revenue which, if improperly handled, can cause serious inflation and corresponding economic distress in those sectors of the economy which are not in a position to benefit directly from the sudden influx of wealth. Labor-intensive industries such as agriculture are severely affected, especially if a government attempts to control the price of foodstuffs in order to avoid an increase in the urban cost of living. Wisely handled, the revenues from a successful oil development can be of inestimable value to a developing country, but history has demonstrated in a number of cases that the damage done to the national economy by improper use of these revenues in the first few years may take decades to rectify.

At the local level, a large oil field or mining development can give rise to substantial population shifts and demands for new roads, educational, and health facilities on a scale which the local administration cannot supply. Since the revenues from such development usually accrue to the central government, it is necessary that the center provides immediate assistance to the local authorities if severe social problems are to be avoided.

A. Oil and Gas Development

Oil and gas development poses a number of problems, some of which are of a general nature and others which are specific to the industry. As mentioned above, it is usual for the petroleum industry to be accorded a special legal and fiscal status. The number of such petroleum laws is large and they are of great variety. The simplest merely authorizes the head of state to make what arrangements he may see fit, while at the other extreme are complex codes which attempt to regulate every detail. The main disadvantage of such detailed legislation is that it is geared to the state of technology at the time of drafting and therefore rapidly becomes out of date. Ideally, a petroleum code should lay down the basic principles upon which government is prepared to allow development of its oil and gas resources, and leave the details to be covered by administrative regulations and model agreements which do not have the force of law and which can readily be modified as circumstances require. For instance, the terms of an agreement negotiated before any discovery has occurred usually need to be more generous than after a discovery.

The principal points which need to be covered in a petroleum law are the following:

(a) What type of legal entity is permitted to carry out petroleum development;

(b) The maximum term for which rights can be granted;

(c) The maximum area which may be held at any time by any given organization, at any stage of the development process;

(d) Where and how the value of any oil and gas produced will be determined;

(e) The principles upon which taxation will be levied upon a producer.

It is not advisable to stipulate the precise amount of taxation in the law itself, since freedom to negotiate this gives a very desirable degree of flexibility to deal with special circumstances such as economically marginal developments. As an example, many petroleum laws drafted prior to 1973 stipulated a tax rate of 50% of net profits, but this became inadequate in the eyes of most governments after the crude oil price rises of 1973, and the petroleum laws concerned were redrafted. This in turn inhibited private investment until the terms of the new laws had been published. Such changes in petroleum legislation and the subsequent renegotiation of agreements with private developers lead to a loss of business confidence. A major objective in designing a petroleum tax code relating to private investment is to avoid the early abandonment of small or marginal fields on the one hand, and the accumulation of huge profits from a major discovery on the other. This can only be achieved by the use of a flexible tax code which takes account of the various possibilities that may result from exploration. The need for such a system is increased as international crude oil prices become more remote from actual production costs.

A major policy issue in petroleum development is whether this is to be undertaken entirely by the state; by means of a parastatal organization which can associate with private (and usually foreign) partners; or by direct grant of development rights to private enterprises (again usually foreign but sometimes associated with local capital). As mentioned earlier, there has been a trend away from total state monopoly towards a mixed system. Examples of this are Brazil, Chile, and Argentina, while Mexico still retains a total state monopoly. The less technologically advanced of the developing countries tend to rely more heavily upon private foreign capital to undertake petroleum exploration and development because they have neither the financial resources nor the technical expertise to undertake it themselves.

When a developing country government decides to permit foreign private capital to participate in petroleum development in its territory, it is then faced with the problem of negotiating a satisfactory agreement which is intended to be legally binding for a period of 20 to 30 years, during which conditions may change drastically. The private oil companies can mount a formidable negotiating team familiar with all aspects of the international petroleum industry, whereas the government is often fortunate if it can count on one or two civil servants who have some knowledge of the petroleum industry. The remedy in such a case is for the government itself to obtain professional advice from consulting firms which specialize in this type of work, of which there are a number. The appropriate time to use these services is at the initiation of the negotiations. It is a waste of time and money for a government to sign an agreement and then seek professional advice as to its appropriateness, as has often happened.

The majority of petroleum laws relate to oil and gas development, and deal with petroleum refining only marginally, if at all. Petroleum refineries range from small simple skid-mounted distillation units processing 1,000 or 2,000 barrels per day of crude oil which can produce only regular grade gasoline, diesel oil, and residual fuel oil, on up to the most sophisticated units processing 300,000 barrels of crude per day or more and producing a full range of refined products and petrochemical feedstocks.

For any country to obtain the maximum benefit from its domestic oil production, a refinery is necessary. However, there are a number of difficult policy issues to be considered in deciding whether or not to construct a petroleum refinery in a developing country, especially if the total product consumption is 50,000 barrels a day or less. There are very large economies of scale in petroleum refining, and it becomes increasingly difficult to match the pattern of product demand to the output of a refinery as the size of the market decreases. The pattern of refined product demand in most developing countries is skewed towards light products (gasoline and diesel oil) with only a limited demand for heavy fuel oil for power generation or industrial use (see Table IV-1). Should the country have developed hydropower resources, demand for heavy fuel oil (also known as residual fuel oil, Bunker C fuel) for power generation is eliminated. On the other hand, even a light crude oil such as Arabian Light will produce 46% of residual fuel oil in a simple refinery. The problem of disposal of excess residual fuel oil from small refineries in developing countries is therefore serious, especially if the refinery is running on imported crude. The usual remedy has been to use a spiked crude feedstock (i.e., a crude oil to which has been added a proportion of semi-refined naphtha and gas oil) in order to increase the yield of light products. These feedstocks cost appreciably more than the original light crude oil and it is questionable how much longer they will be readily available, in view of the increasing worldwide demand for light products and the trend towards oil refining in producing countries.

The fuel oil problem is made worse by two factors; firstly, the fuel oil produced in a small refinery rarely meets international specifications for sulphur content and viscosity, and must therefore be discounted heavily in order to sell it; secondly, almost all the alternative energy sources which are being developed to replace imported oil displace only heavy fuel oil, not light products. The result has been a downward pressure on the price of heavy crude, which produces a higher proportion of heavy fuel oil (see Diagram IV-1) than the lighter crudes which are increasingly sought by both developed and developing country refiners.

One possible solution to the excess fuel oil problem is the addition of secondary refining plant, known as a cracker, to the refinery, which will convert a proportion of the heavy fuel oil into light products. The problem here is one of the minimum size of cracker which is economically viable, and its cost. Broadly speaking, a cracker is designed to process about one-third of the nominal distillation capacity of the refinery, but it approximately doubles the capital cost of the plant (see Tables IV-2 and IV-3).

If the cost of a cracker cannot be justified, it becomes questionable whether a small refinery in a developing country is economically viable at present-day crude oil prices, if there is no internal market for heavy fuel oil. Some developing countries may be faced in the not-too-distant future with the decision as to whether or not to close down the local refinery and import only refined products. This is rendered more likely by the present worldwide excess of refining capacity, which is likely to persist for some years. While there is a natural aversion on the part of governments to closing down a major industrial plant, it makes little sense to subsidize the operation of an uneconomic refinery if the direct import of refined products would be cheaper. A refinery by itself is no guarantee of security of supply. This can only be provided by carrying excess stocks in storage, which can be done as easily for refined products as for crude oil.

Table IV.1: INLAND CONSUMPTION OF REFINED PRODUCTS IN DEVELOPING COUNTRIES, 1960, 1965, 1970

	Gasolines	Kerosenes	Distillate Fuel Oil	Fuel oils[a]	Others[b]	Total domestic demand
Latin America			(thousand barrels daily)			
1960	397	115	256	584	235	1 587
1965	507	147	341	709	392	2 096
1970	683	198	476	840	476	2 673
			(per cent distribution)			
1960	25·0	7·2	16·2	36·8	14·8	100·0
1965	24·2	7·0	16·3	33·8	18·7	100·0
1970	25·6	7·4	17·8	31·4	17·8	100·0
Africa			(thousand barrels daily)			
1960	63	33	72	99	42	309
1965	79	48	123	159	51	460
1970	91	67	143	152	57	510
			(per cent distribution)			
1960	20·5	10·7	23·4	31·9	13·5	100·0
1965	17·1	10·6	26·7	34·6	11·0	100·0
1970	17·8	13·1	28·1	29·8	11·2	100·0
Asia			(thousand barrels daily)			
1960	151	140	224	390	171	1 076
1965	225	222	322	674	205	1 648
1970	310	418	553	1 081	373	2 735
			(per cent distribution)			
1960	14·0	13·0	20·8	36·3	15·9	100·0
1965	13·6	13·5	19·5	40·9	12·5	100·0
1970	11·3	15·3	20·2	39·6	13·6	100·0
Total developing countries			(thousand barrels daily)			
1960	611	288	552	1 073	448	2 972
1965	811	417	786	1 542	648	4 204
1970	1 084	683	1 172	2 073	906	5 918
			(per cent distribution)			
1960	20·6	9·7	18·6	36·1	15·0	100·0
1965	19·3	9·9	18·7	36·7	15·4	100·0
1970	18·3	11·5	19·8	35·1	15·3	100·0

[a] Including bunkers.
[b] Includes lubes, refinery fuel, losses and others products.

Source: United Nations Interregional Seminar on Petroleum Refining, New Delhi, 1973.

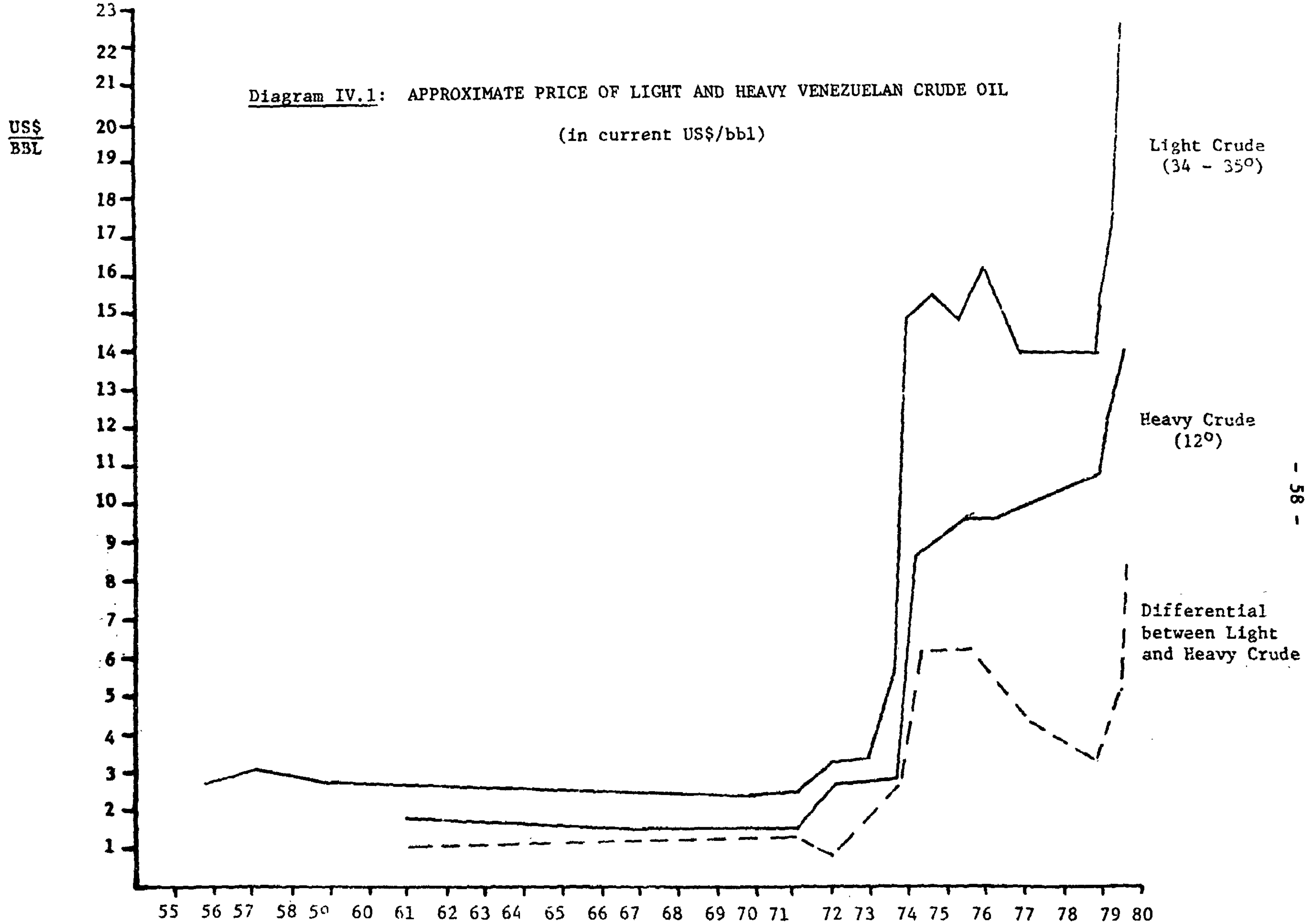

Diagram IV.1: APPROXIMATE PRICE OF LIGHT AND HEAVY VENEZUELAN CRUDE OIL

(in current US$/bbl)

Light Crude - Oficina (34-35° API) Heavy Crude - Monagas (12° API)

Source: Platts Price Service Oilgram, Petroleum Intelligence Weekly.

Table. IV.2: REFINERY INVESTMENT COST

Primary Distillation Capacity 1/ ('000 Bbls/day)	Total Investment Cost (million $)
20	20 - 40
60	55 - 85

1/ The capacity of a catalytic cracking unit is one-third the primary distillation capacity of the refinery.

Source: Verbal information from construction companies.

Table IV-3: CAPITAL COST OF FLUID CATALYTIC CRACKING UNITS IN REFINERIES (in millions of 1979 US dollars)

Thousand Bbls. per Stream Day	Bare Cost (million $) 1/	Total Investment Cost (million $) 1/	Total Investment $/Bbl. per stream day
7.5	12	15	2,000
20	24	28	1,400
40 2/	40	45	1,125
60	54	59	983

1/ Total Investment Costs include interest during construction, royalties, overhead and profit which are not included in Bare Costs. Both Bare Costs and Total Investment Costs include standard pollution control equipment but not special SO_x pollution control equipment.

2/ Hydro cracking for a 40,000 bbl per stream day costs 1.5 -2 times the cost of a catalytic cracker.

Source: Verbal information from construction companies.

Natural Gas

The utilization of natural gas in a developing country has become economically far more attractive as crude oil prices increase, but nevertheless often presents a number of severe problems which call for policy decisions. While natural gas itself is a highly desirable fuel for both domestic and industrial use, it must be transported, in most cases by pipeline. 1/ Hence the market needs to be sufficiently large and concentrated to justify the cost of constructing not only the gas processing plant but also the pipeline to supply it. Representative gas pipeline costs in developing countries are of the order of $10 million to $13 million per 100 kilometers for a 15 inch diameter line which could transport about 75 million cubic feet of natural gas per day. This amount of gas is equivalent in terms of heating value to 13,500 barrels of oil per day and it is rare to find a concentrated market of this magnitude in developing countries. An eight inch diameter line would cost about $7 million to $10 million per 100 kilometers but would transport only 20 million cubic feet of gas per day under similar conditions, equivalent to 3,600 barrels of oil per day. There is, therefore, little saving in construction cost in reducing the diameter of the pipeline. Operating costs of pipelines are very low in comparison to fixed capital charges.

To provide a market of adequate size it is necessary to have a grouping of large fuel consumers such as thermal power generating stations, cement plants, nitrogenous fertilizer plants, and similar energy-intensive plants. While many developing countries have such plants, they are rarely grouped in the same area. In most developing countries there is no demand for space heating. In considering natural gas development, therefore, it is often necessary to build the market at the same time as the transport facility since an underutilized pipeline is an uneconomic investment. Further investment costs are incurred if it is proposed to utilize associated gas from oil fields, since this must be collected from a number of dispersed sources of supply, treated, and compressed before being put in the pipeline. An additional complication is that in many cases natural gas competes with fuel oil or hydro-power for the same market, so that natural gas development may actually increase problems in other parts of the economy. It is, therefore, not uncommon to find unexploited natural gas resources in countries which are having difficulty in obtaining foreign exchange to pay for oil imports. Frustrating as this may be, there is no easy solution to the problem at the present time. Nevertheless, developing countries having natural gas reserves should make a serious attempt to utilize them.

B. Coal Development

While coal resources are not as widely distributed in developing countries as is potential for oil and gas production, nevertheless a substantial number of developing countries have coal deposits which could be developed

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1/ Natural gas can be liquefied by refrigeration and so transported, but the cost of doing so is such that this is only feasible at present for large export-oriented plants. A liquefaction plant for 500 million cubic feet of gas per day costs about $1 billion, and ocean tankers to ship it cost as much again.

for domestic use, while a few have deposits of good quality steam coal which might be developed for export. Even good quality coal has only about three-quarters of the heating value of an equivalent weight of fuel oil, and many of the coal deposits in developing countries are of low quality. However, even a very low quality coal can be used for power generation provided that the coal can be mined cheaply and the generating plant is located at the mine. In general, low grade coal must be used at or close to the source, otherwise the cost of transporting it renders it uncompetitive with fuel oil even at present-day prices.

Small-scale coal mining for local use does not present many policy problems, but a large-scale development to support industrial growth presents many. First and foremost is the cost of developing the mines and need for infrastructure such as transport and community facilities for the miners and their families. Table IV-4 gives some representative costs for coal mine development. Large-scale transport of coal is effected for the most part by rail. Water transport is very suitable for this type of traffic but it is rare to find a situation where this is feasible. Since the cost of building a railroad and handling facilities to transport the coal is very high, in developing countries which propose to develop coal as an industrial fuel, serious consideration should be given to setting up the industrial development in the coal field, rather than transporting the coal to existing population centers.

Many low-grade coals can be improved in quality by mechanical washing to reduce ash content, and by partial carbonization to reduce water content, sulphur, and the volatile matter which gives rise to most of the smoke from coal burning. Such smokeless fuels can often be compressed into briquettes which are easier to transport than the original raw coal and which provide a useful fuel for domestic purposes and for light industry. In developing countries suffering from shortages of domestic fuel and consequent deforestation, serious consideration should be given to exploiting coal deposits to make smokeless fuel briquettes as a substitute. The briquetting potential of each coal deposit needs to be determined separately, by experiment, so that an appropriate technical process can be used. Many of the failures reported in this type of project result from lack of proper investigation of the properties of the coal before purchasing the plant.

There has been much discussion about the production of synthetic liquid fuels from coal as a result of the present high price of refined petroleum products. While coal itself can substitute for fuel oil in most industrial applications, the manufacture of synthetic liquid fuels from coal offers one of the very few possibilities of substitution for petroleum fuels in the transport sector, i.e., for gasoline and diesel fuel. The technology is fairly well known, having been used extensively in Germany during the Second World War. The only plants operating at the present time are located in South Africa, although there are a number of pilot plants in the USA. The problem is less one of technology, although the plants have had considerable start-up problems, than of cost. It is reported that, provided the cost of coal at the plant is below $10 per ton, it should be possible to produce synthetic automotive fuel from coal at around $40 to $50 per barrel. This is considerably below the retail prices (including taxes) at which such fuels are sold in most countries at the present time.

Table IV-4: COAL PRODUCTION AND MINE INVESTMENT COSTS IN SELECTED COAL PRODUCING COUNTRIES

	Mining Technology	Coal Type	Minehead Production Cost Existing Mine US$/ton-1978	Minehead Production Cost New Mine US$/ton-1978	Incremental Mine Investment Cost US$/ton-1978
DEVELOPED MARKETS					
Australia	S	B,C,L	12-15	8-15	30-40
Canada	U	B,C	20-45	n.a	40-50
	S	S,B,L	6-15	n.a	20-30
France	U	B	80-95	80-90	n.a.
		L	35-45	n.a.	
Germany, F.R.	U	B,C		70-100	70-85
		L	10-25		
South Africa	U	B,C	10-12	n.a	30-35
	S	B,C	8-10	n.a	n.a
United Kingdom	U	B,C	45-75	n.a	70-80
U.S.A	U	B,C	20-30	n.a	40-55
	S	B,L	8-15	n.a	10-35
CENTRALLY PLANNED ECONOMIES					
China, P.R.	U	B,C	12-20	n.a	25-35
	S	B,L	6-12	n.a	5-10
Czechoslovakia	U	B,C	30-40	n.a	60-70
Germany, D.R	S	L	8-12	n.a	15-25
Poland	U	B,C	18-25	n.a	50-60
	S	L	5-10	n.a	15-20
U.S.S.R.	U	B	18-25	n.a	30-40
	S	L	5-10	n.a	15-20
DEVELOPING COUNTRIES					
Argentina	U	B	40-45	n.a.	50-60
Brazil	U/S	B	15-25	12-18	25-50
Colombia	U	B,C	5-22	n.a	n.a
	S	B	n.a	25-30	50-60-
India	U	B,C	12-25	n.a	30-35
	S	B,L	20-22	n.a	n.a
Indonesia	U	B	35-40	n.a	n.a
	S	B	18-20	30-35	50-60
Korea, Rep.	U	A	20-25	n.a	35-40
Mexico	U	B,C	15-20	n.a	45-55
Pakistan	U	B	20-30	n.a	n.a
Philippines	U	B	8-21	18-20	30-70
Thailand	S	L	n.a	7-12	30-35
Venezuela	S	B	n.a	20-25	50-55
Yugoslavia	U	S,B,L	20-25	n.a	25-30
	S	S,B,L	11-16	n.a	10-20

LEGEND: Mining Technology
U = underground mine
S = surface mine

n.a. = not available

Coal Type
A = anthracite
B = bituminous
C = coking coal
S = sub-bituminous
L - lignite

Sources: Skelly and Loy; IBRD data.

The principal problems from the point of view of a developing country, however, are the massive investment cost and the complex technology involved. The latest plant to be constructed in South Africa is reported to have cost around $3 billion and to require a coal input of 40,000 tons per day for an output of 4,400 tons of gasoline/diesel fuel per day, or 37,500 barrels per day. (Output is 92% gasoline.) While there are numerous other outputs in the form of solvents, petrochemical feedstocks, and town gas, it is the liquid fuel output which is the main reason for constructing such a plant. Although the process does not require a high quality coal feedstock, the size of the coal reserve required for a single plant of the size discussed (around 500 million tons) and the high cost of the plant will limit the number of developing or developed countries which can contemplate the production of synthetic automotive fuels from coal, unless technological improvements in the future can both reduce the cost of the plant and improve the conversion efficiency.

Some of the industrialized countries (notably Japan) are already large importers of steam coal, as distinct from coking coal used in iron ore smelting. There have been suggestions that developing countries should consider the import of coal for power generation and industrial purposes as a substitute for oil. As explained earlier, coal would only substitute for heavy fuel oil and where a petroleum refinery is in operation there is likely to be a surplus of heavy fuel oil. Tables IV-5 and IV-6 show representative f.o.b. and c.i.f. prices for coal in international trade. These show that although the price of coal has risen between two and three times since 1973, it is still relatively cheap in comparison with imported fuel oil which is quoted at around $110 to $130 1/ per ton ex-refinery, which on the basis of calorific value alone would equate with f.o.b. prices of $82 to $105 per ton for high quality steam coal.

There are, however, a number of additional costs in using coal as a boiler fuel as compared with fuel oil; for example, the cost of installing coal handling and transport facilities where these do not exist, and the additional cost of coal-burning boilers as compared with fuel-oil fired boilers, which is of the order of 30% to 40%. Any decision to switch from oil to coal as a basic fuel needs to take account of all the various factors mentioned above, and also the effects of changes in ocean freight rates, as well as forecasts of f.o.b. prices, on the final delivered price of coal to the consumer.

C. Policy Issues Related to Oil Shale and Tar Sand Development

Despite the physical differences between these two types of resource, they are sufficiently similar from the policy point of view to be considered together. Both are low-grade resources with high development and processing costs which, nevertheless, offer a possibility of providing the automotive fuels normally obtained from crude oil, and for which there is no effective substitute at the present time.

1/ Petroleum Economist.

Table IV.5: SPOT STEAM COAL PRICE TRENDS FOR SELECTED COUNTRIES [1/]

	SUPPLY					
	Specifications			FOB Value (US$/metric ton)		
Country/Port	BTU/lb	Sulphur(%)	Ash(%)	July 1977	July 1978	April 1979
U.S.						
Ashtabula/Conneaut	12,500	2.00	12.0	25.50	34.30	33.30
Hampton Roads/Norfolk	12,000	<1.00	12.0	30.90	39.90	32.30
Baltimore	12,500	<1.00	12.0	24.50	33.30	37.70
Duluth	9,500	0.60	27.0*	18.10	27.40	26.90
POLAND						
Gdansk/Swinoujscie	11,800	1.00	15.0	21.60	26.50	26.50
S. AFRICA						
Richards Bay	11,300	1.00	15.0	21.60	20.10	20.10
INDIA						
Hadia/Pradip	11,200	<0.60	16.0	19.60	21.10	21.10
AUSTRALIA						
Newcastle/Port Kembla	12,000	<1.00	13.0	24.50	29.90	29.90

	DEMAND					
	Specifications			CIF Value (US$/metric ton)		
Country/Port	BTU/lb	Sulphur(%)	Ash(%)	July 1977	July 1978	April 1979
ARA/FRANCE /2						
	11,000	1.00	12.0	30.40	30.40	20.40
	12,000	<1.00	12.5	37.20	35.80	47.00
SPAIN	11,200	< 1.50	11.0	29.90	30.90	30.90
	11,700	1.00	23.5	30.90	31.90	31.90
UK	10,800	1.00	17.0	30.90**	30.90**	30.90**
GERMANY (F.R.)	11,300	1.30	12.5	32.30	33.30	34.30
	12,200	1.20	13.0	38.20	34.30	42.10
TAIWAN	11,500	1.00	16.0	35.80	35.80	35.80
	11,300	<1.00	13.0	33.80	33.80	33.80

* Moisture included.
** Contract quote.
FOB = Value at the port of exportation based on the transaction price which includes packing, inland freight, dock delivery, loading charges and all other expenses up to the point where the merchandise is deposited on board the exporting vessel.
CIF = Cash, insurance and freight, delivered at the port of entry.

/1 Price quotes are for spot sales, defined as single shipments or volumes to be delivered within one year.
/2 Amsterdam, Rotterdam, Antwerp, France.

Source: "Coal Week", July 1977, July 1978, April 1979.

Table IV.6: HISTORICAL COAL TRADE VALUES FOR SELECTED COUNTRIES (1972-76)

(US$/metric ton)

Producing Countries:	Australia			Poland			Canada		
Year	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif
1972	6-9	20	18	-	22-24	24	-	13	21
1973	7-9	18-22	20	-	22-25	24	13	-	22
1974	16-17	26	30	-	32-39	39	-	14	31
1975	16-26	40	39	-	42-57	57	18-32	36	48
1976	14-31	45-48	51	-	36-59	59	20-33	-	58

Producing Countries:	F. R. of Germany			Mozambique			South Africa		
Year	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif
1972	23-37	31-55	-	-	-	17	-	7	19
1973	24-39	36-37	-	-	-	-	-	24	18
1974	44-50	42-44	-	-	-	37	-	30-40	34
1975	59-64	54-65	84	-	-	47	15	28-50	43
1976	72	44-70	-	-	-	43	21	30-32	41

Producing Countries:	United Kingdom			USSR			USA		
Year	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif
1972	-	12-35	-	-	14-18	21	21	23-30	29
1973	-	12-29	-	-	14-17	21	23	24-29	30
1974	-	37-44	-	-	19-32	33	48	42-53	63
1975	29-41	40-56	-	-	30-58	50	59	50-73	73
1976	32-46	44-53	-	-	32-48	52	58	48-59	68

Notes: (1) All values have been calculated on a tonnage basis without consideration of quality differences.

(2) fob = free on board value at the port of export, based on the transaction price including packing, inland freight, dock delivery, loading charges and other expenses up to the point where the merchandise is deposited on board the exporting vessel.

(3) cif = cash, insurance and freight delivered at the port of entry, values for Japan include only bituminous exports (mostly coking coal), while those for Western Europe include both bituminous coal and anthracite.

Sources: World Coal Trade, 1973-75; International Coal (formerly World Coal Trade), 1976-77; Commodity Trade and Price Trends, IBRD, 1978.

The principal issues involved are:

(a) Determination of the extent of the resource, since this is rarely known;

(b) The choice of labor-intensive low-technology extraction methods, or capital-intensive high-technology. For most developing countries there would seem to be an obvious advantage in the former method since it permits them to invest a maximum of indigenous resources with a minimum of external requirements in the form of capital and expertise;

(c) Obtaining the necessary finance. This is a derivative of the first two points, and in fact is not usually possible until the size and nature of the resource is known;

(d) Deciding whether to develop the resource if the previous factors have been determined. While it might appear that this is a foregone conclusion, even if studies show that liquid fuels can be produced more cheaply than by importing crude petroleum or refined products, there are a number of other factors which need consideration. For example, neither the processing technology nor the volume of output are easily changed, once capacity has been installed. This can lead to problems as the pattern of market demand changes, or if there are wide fluctuations in demand due to seasonal factors or changes in economic activity. Both shale oil and tar sand extraction plants resemble base-load power stations, and decline rapidly in economic efficiency if their output is restricted for any reason. For these reasons, the decision to develop a resource of this nature requires careful study.

CHAPTER V

OPTIONS FOR THE DEVELOPMENT OF ELECTRIC POWER

A. Introduction

The demand for electric power in developing countries has grown more rapidly than for any other energy form, and it is projected to grow even more rapidly in the future, with growth rates surpassing those of industrialized countries. Provision of electric power is an important part of the developmental process, in industry, in the municipal and domestic sectors, and for improving standards of living and productivity in rural areas.

Recent growth in electricity production has averaged 9 percent per annum in developing economies. Based on existing expansion plans, this trend is likely to continue during the 1980s. The geographic patterns of likely capacity expansion are shown in Table V.1.

Table V.1: DEVELOPING COUNTRIES: INSTALLED GENERATING CAPACITY, BY REGION

(millions of kilowatts)

Region	1976	1980	1985	1990	1977-1990 Additions
West Africa	4.1	5.8	8.7	13.8	9.7
East Africa	5.0	6.8	7.8	10.4	5.4
Europe, Middle East and North Africa	52.5	82.2	126.9	188.3	135.8
South Asia	26.4	40.6	62.1	90.0	63.6
East Asia and Pacific	26.3	39.8	69.6	116.0	89.7
Latin America and Caribbean	59.0	80.1	114.9	160.8	101.8
Total	173.3	255.3	390.0	579.3	406.0

Electric power is generated in thermal plants burning oil, gas, or coal, and from hydro, geothermal, and nuclear power plants. Which of these sources is selected depends on their availability and on the relative cost of electricity generated. The cost of electric power generation varies not only with the fuel used, but also with the type of generation technologies, the type of load (base, cycling or peak), pollution control technology requirements, and load factors.1/

Table V.2 shows that installed hydro capacity in the developing countries is expected to be nearly triple the 1976 figure by 1990, but despite this, conventional thermal generating capacity will still predominate. This latter category includes a variety of generating equipment, ranging from light high-speed diesel units for small isolated load centers up to two Megawatts, slow-speed diesels using heavy fuel oil for units in the range 2-20 Megawatts, gas turbines for peaking capacity in the range 20-40 Megawatts, and steam turbine plants in the range 20-100 Megawatts. The latter may burn heavy fuel oil, natural gas, coal or lignite of various grades.

Table V.2: INSTALLED GENERATING CAPACITY IN THE DEVELOPING COUNTRIES (millions of kilowatts)

Type	1976	1980	1985	1990	1977-1990 Additions	
Hydro	70.4	101.0	149.5	205.8	135.4	(33.3%)
Geothermal	0.1	0.4	1.4	2.3	2.2	(0.5%)
Nuclear	1.2	4.3	22.1	62.4	61.2	(15.1%)
Thermal	101.6	149.6	217.0	308.8	207.2	(51.1%)
Total	173.3	255.3	390.0	579.3	406.0	(100.0%)

The recent rapid rise in fossil fuel prices has made many previously marginal hydropower projects economic. Many projects that would previously have been economic only if built for multipurpose applications are now economically viable when built solely for generating electricity. According to estimates made by World Bank staff, the cost per kilowatt-hour of electricity generated in an oil-fired power plant has risen from 9 to 20 mills2/ in the past five years, while the cost of electricity

1/ The load factor is the percentage of the total energy generation potential which is actually generated and used in any one year.

2/ One mill = 1/10 of a U.S. cent.

from existing large-scale hydro plants has remained stable. Although the operating costs of hydropower plants are minimal, the capital cost per kilowatt of installed hydropower is nearly twice the capital cost per kilowatt of a thermal power plant, as shown in Table V.3.

Table V.3: AVERAGE SYSTEM COST PER KILOWATT OF INSTALLED CAPACITY (in 1977 U.S. dollars)

Hydro	1,296
Geothermal	1,564
Nuclear	1,436
Thermal	863

Interconnection of several countries' hydropower or thermal power systems can effect savings through larger unit sizes, reduced system reserves, differences in peak load times, higher load factors, and thermal back-up of hydro systems. The interconnection of several small systems permits the group to gain some of the benefits of a large power pool. Areas offering prospects for regional interconnection are West Africa (interconnecting Nigeria through Guinea) in the long term and Central America in the near term.

B. Coal vs. Oil Fired Power Generation

Since 1973 oil prices have risen 270 percent in real terms while average coal prices have risen 42 percent. This new structure of fossil fuel prices leads to consideration of two alternatives: (1) converting existing power stations from oil to coal firing; (2) supplying additional generating capacity by building coal fired plants instead of oil fired plants.

Conversion of existing steam plants from oil to coal firing might appear, at first glance, to offer scope for economies. However, two factors have deferred any major conversion of existing stations to coal in the developing countries: (a) fuel transportation costs on a heat content basis are higher for coal (12,000 BTU/lb) or lignite (6,000 BTU/lb) than oil (18,500 BTU/lb); and (b) coal conversion requires major investment for boiler modification, coal pulverizers, storage and handling facilities, ash precipitation, and scrubbers.

While conversion of oil plants to coal cannot be expected on a large scale, building new coal fired plants to burn indigenous or imported coal may be an economically viable option for many developing countries

Table V.4: APPROXIMATE CAPITAL COST OF SMALL COAL AND OIL FIRED ELECTRICAL PLANTS

(in June 1979 U.S. Dollars)

Plant Size	25 MW[1/]	50 MW	100 MW	150 MW	200 MW	300 MW
Coal Fired						
Direct Costs[2/] (mill. $)	24.4	39.2	65.8	88.3	109.8	149
Indirect Costs (mill. $)	8	10	12.5	15.4	17.5	20.7
Contingency (mill. $)	1.8	2.8	4.7	6.3	7.7	10.3
Total (million $)	34.2	5.2	83	110	135	180
$/KW	1,368	1,040	830	733	675	600
Oil Fired						
Direct Costs (mill. $)	20.5	32.9	54.8	74	91.9	124.1
Indirect Costs (mill. $)	6.7	8.5	10.3	12.8	14.7	17.3
Contingency (mill. $)	1.5	2.4	3.9	5.2	6.4	8.6
Total (million $)	28.7	43.8	69	92	113	150
$/KW	1,148	876	690	613	565	500

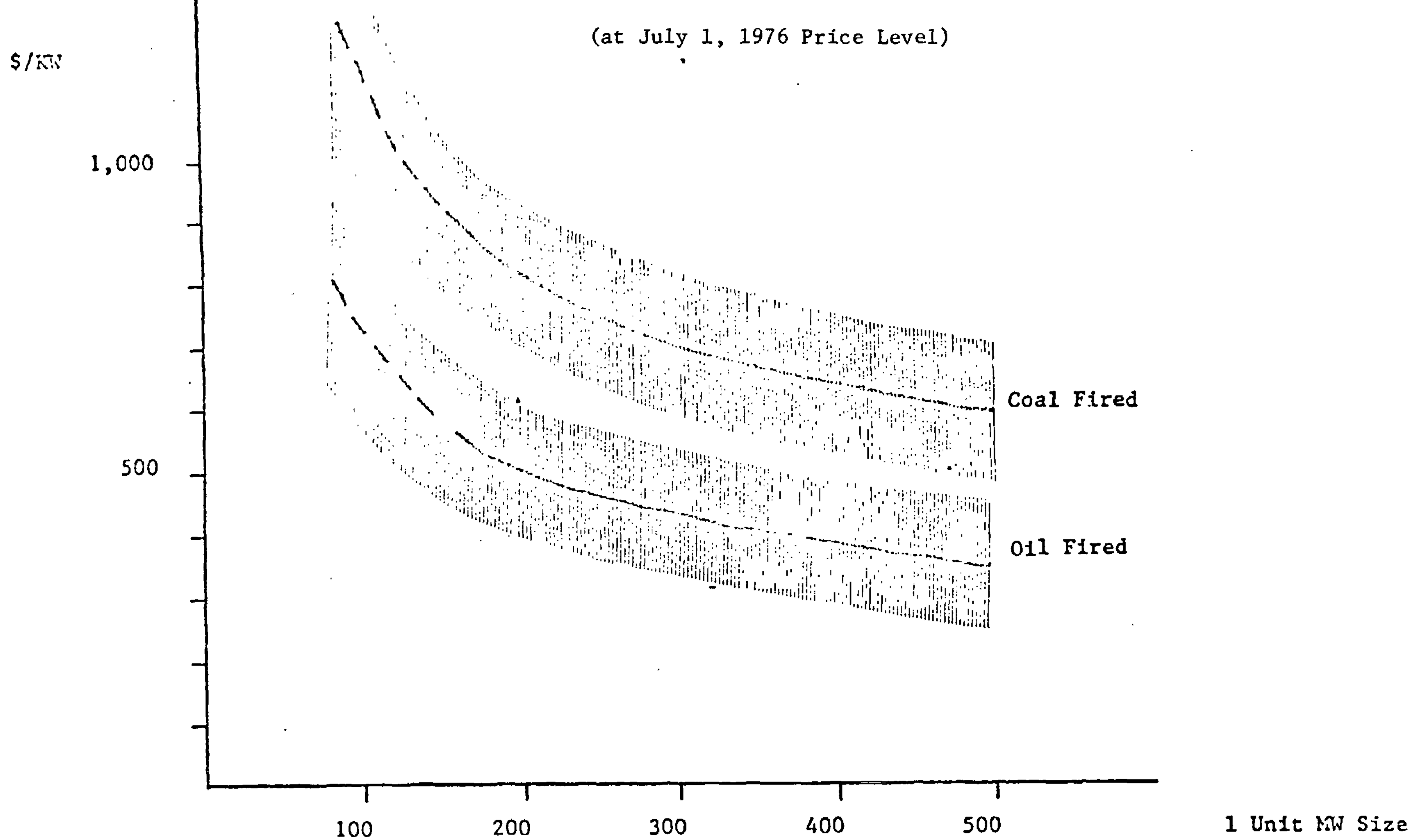
1/ Estimates based on limited information since 25 MW plants are rarely built.

2/ Costs and Contingency in millions of U.S. 1979 dollars. Baseline estimates of Direct and Indirect Costs are based on UENC Definitions. Interest during construction, owner's cost, switchyard, waste disposal, taxes, and flue gas desulfurization equipment are not included. Exact details of plant scope according to UENC definitions can be found in (NUREG 0241-0248).

Source: United Eng. and Constructors Inc., Philadelphia, Pa.

Figure V.1: CAPITAL COST OF OIL AND COAL FIRED STEAM ELECTRICITY GENERATING PLANTS WITHOUT FLUE GAS DESULFURIZATION EQUIPMENT 1/

(at July 1, 1976 Price Level)

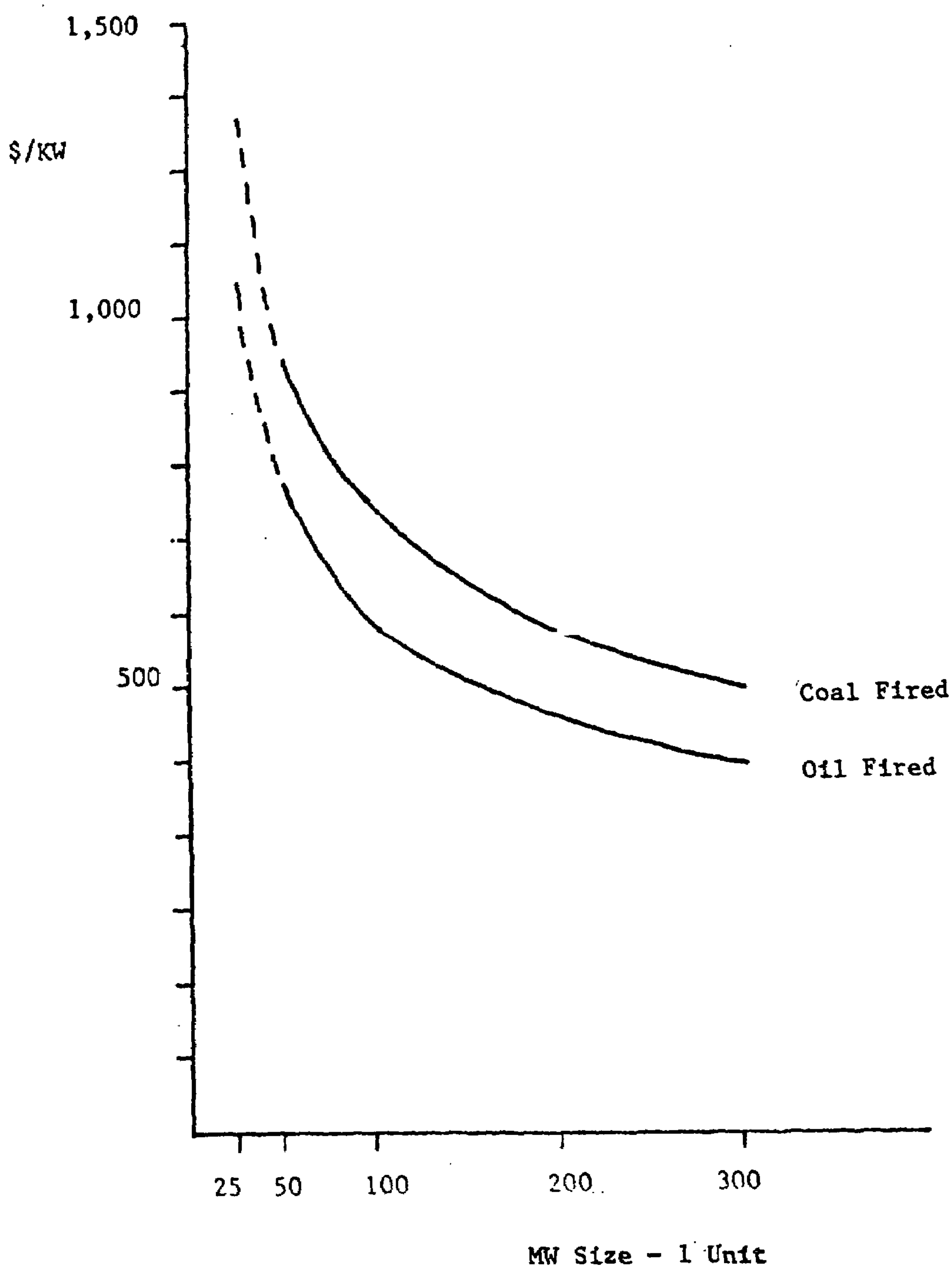


1/ FGD cost adds approximately $100/KW for a 1 x 500 MW plant. Range shown is based on the range of six recently constructed 1 x 500 MW plants.

Source: EPRI Report AF-342, Jan. 1977, Bechtel Power Corp.

Figure V.2: APPROXIMATE CAPITAL COST OF SMALL COAL AND OIL FIRED PLANTS WITHOUT FLUE GAS DESULFURIZATION EQUIPMENT

(June 1979 dollars)



Interest during construction, owners' cost, switchyard, waste disposal, FGD and taxes not included. Details of plant scope according to baseline UENC definitions can be found in NUREG 0241-0248, NTIS.

Source: United Eng. & Constructors, Inc., Phil., Pa.

(notably India, Indonesia, Tanzania, Mozambique, Chile). The capital cost of a new oil fired plant is 60 percent to 80 percent of the cost of a new coal fired plant as shown in Table V.4, figures V.1 and V.2. This is largely due to the fact that the boiler for a coal plant costs twice that for an oil plant. But depending on the plant's location and the local differential between oil and coal prices, power from new coal fired plants may be cheaper than power from new oil fired plants. An additional cost in the case of imported coal is the need to construct bulk handling facilities and storage in the port area. The costs and reliability of coal fired plants must be weighed against similar factors relating to alternative electrical generation schemes (hydro, geothermal, and nuclear) before a decision can be reached in the course of planning.

C. The Geothermal Option

Geothermal power resembles hydropower in its capital structure in that it has a relatively high initial capital cost followed by low operating costs, and no fuel requirements. It has the further advantage that it can be constructed in increments as power demand increases. The low steam pressures in geothermal fields mean that electricity is generated from a large number of relatively small units (30-50 MW), giving a relatively high system reliability for a stated level of output. Problems associated with development are the corrosive nature of the steam, the high noise level associated with wet steam fields, and the need to dispose of very large quantities of hot mineralized water from wet steam fields. Development problems with dry steam fields are fewer, but so far the only dry steam fields which have been developed are Larderello in Italy and the Geysers in California (USA).

D. The Nuclear Option

The low proportion of nuclear power costs represented by fuel supply, and the apparent security from interruption, have led to intensive study of nuclear power development, as offering freedom from dependence on imported oil. For most developing countries, except for a few of the largest and most technically advanced, these advantages are largely illusory. Problems relating to nuclear power in a developing country context are:

(i) very high capital cost;
(ii) dependence on imported technology;
(iii) the fact that the smallest available power generating reactor is large in relation to the system size in most of these countries;
(iv) international agreements and restrictions on fuel supply.

In 1977 only three developing countries, India, Pakistan, and Argentina had operating power reactors. Brazil, Mexico, and the Republic of Korea are in an advanced stage of planning for nuclear installations.

Opposition to nuclear energy is widespread and is generally of a political and emotional nature, but in addition, existing plants have in some cases had a disappointing operational record. The principal objections to nuclear power center around the problems of radioactive waste disposal, security and safety. In considering the sheer number of reactors that will be required for this technology to make an appreciable contribution to the total world energy supply by the turn of the century, these arguments admittedly have some validity. Consequently, while forecasts of nuclear power capacity still show large increases up to 1985, most of these increases originate from plans made some years back for plants which are now under construction. Table V.5 presents the total nuclear capacity expected to come on line between 1978 and 1990 in developing countries, by country. These estimates are based on a recent study by the International Atomic Energy Agency (IAEA) and include operating reactors plus those under construction and firmly planned. It is difficult to estimate how much of the apparent slowdown in the growth of capacity after 1985 is simply due to the absence of firm plans for the years between 1985 and 1990, and how much represents actual decisions not to build nuclear plants.

Nuclear energy is the most capital-intensive source of energy and requires 1.5 to 2.5 times as much capital as comparable oil- or coal-fired electric power plants, but its fuel cost is one-half to one-sixth as much. Nuclear fuel costs are a function of the price and availability of uranium and plutonium and the cost of processing these into fuel elements. The rapid growth in the use of uranium is likely to exert upward pressure on nuclear fuel prices unless new uranium ore discoveries are made, or new nuclear fuel technologies, such as breeder reactors, become technically and economically feasible as well as politically acceptable.

The cost of nuclear power plants has escalated rapidly, rising by a factor of two to three in recent years. Developing countries are at a disadvantage relative to developed countries in adopting nuclear power technology due to shortages of capital, skilled labor and management, and the relatively large size (600 MW) of commercially available power plants. Such plants are normally operated as base-load generators and are too large to be incorporated into the power systems of the smaller developing countries. The light water type of reactors also use enriched uranium fuel which is subject to controls by the exporting countries. Apart from the industrialized countries, only the following could economically utilize a 600 MW size nuclear reactor in their system: India, Brazil, Pakistan, Israel, Argentina, Egypt, Iran, the Republic of Korea, Mexico, the Philippines, Romania, Thailand, and Yugoslavia. (The first seven of these countries have not ratified the nuclear non-proliferation treaty.)

Table V.5: DEVELOPING COUNTRIES: REACTORS OPERATING, UNDER CONSTRUCTION AND PLANNED AS OF MAY 1978

	Operating Reactors		Under Construction		Reactors Planned		Total	
	No.	NEP 1/	No.	NEP 1/	No.	NEP 1/	No.	NEP 2/
Argentina	1	0.3	1	0.6	1	0.6	3	1.5
Brazil	-	-	3	3.1	-	-	3	3.1
India	3	0.6	5	1.1	-	-	8	1.7
Iran	-	-	4	4.2	4	4.8	8	9.0
Israel	-	-	-	-	1	0.6	1	0.6
Korea, Republic of	1	0.6	2	1.2	2	1.8	5	3.6
Mexico	-	-	2	1.3	-	-	2	1.3
Pakistan	1	0.1	1	0.6	-	-	2	0.7
Philippines	-	-	1	0.4	2	1.4	3	1.8
Thailand	-	-	-	-	1	0.6	1	0.6
Turkey	-	-	-	-	1	0.6	1	0.6
TOTAL DEVELOPING	6	1.6	19	12.5	12	10.4	37	24.5
TOTAL INCL. CPEs.	215	102.4	231	209.2	141	135.3	587	446.9

Source: International Atomic Energy Agency.

1/ Net electrical power in GW (thousand MW).

2/ Does not take possible closures into account.

The environmental, security, safety, and health problems of nuclear power plants have been vigorously debated in industrialized countries and should be of equal concern to developing countries. Problems include minor amounts of radioactivity in water and air used for cooling purposes, danger from accidents or sabotage, and a serious problem in disposal of highly radioactive spent fuel. Problems of decommissioning at the end of the economic life of a nuclear power plant have not yet been solved.

The rate of nuclear development in a developing country cannot be considered solely in terms of system size and the economic comparison of nuclear power with other power sources. The analysis of nuclear power must encompass many other issues, among which are the high cost of introducing a new and complex technology, fuel availability, fuel recycling, environmental factors, fuel safeguards, national/international political repercussions, and public acceptability.

E. Capital Requirements for Power Generation

Required capital expenditures in the developing countries for power facilities commissioned during the period 1977-1990 have been forecasted using estimates of system unit costs (including an amount for transmission and distribution facilities) in 1977 US$ for each type of capacity in each country. The estimates represent the capital costs to the electric utilities including duties and taxes, if applicable. Estimates for predominantly hydro systems vary from $850/kW for high-head installations in Colombia to $2,500/kW for small installations in Africa. Thermal system cost estimates vary from $600/kW in Bharain with gas turbines and a concentrated system to $1,450/kW in the Sudan with diesels and small steam units and a high import duty.

The average unit costs for the six regions vary from a low of $942/kW for Europe, Middle East and North Africa, where about two-thirds of the additions will be relatively large thermal stations, to $1,572/kW for small installations in scattered systems in West Africa. The range of regional costs is shown below:

Table V.6: AVERAGE REGIONAL COSTS OF NEW POWER FACILITIES PER KW INCLUDING TAXES AND DUTIES

U.S. Dollars ($ 1977)

West Africa	1,572
East Africa	1,134
Europe, Middle East and North Africa	942
South Asia	1,157
East Asia and Pacific	1,100
Latin America and Caribbean	1,219
Average for 97 Countries	1,097

The estimated capital expenditures required for power facilities commissioned during the period 1977-1990 in the six regions are as follows:

Table V.7: REGIONAL CAPITAL EXPENDITURES REQUIRED FOR NEW POWER FACILITIES

U.S.$ Billions($ 1977)

West Africa	15.1
East Africa	6.2
Europe, Middle East and North Africa	127.9
South Asia	73.5
East Asia and Pacific	98.7
Latin America and Caribbean	124.2
Total	445.6

The following table shows the estimate of the total capital expenditures for 1977-1990 by type of capacity (including related transmission and distribution) for the entire system, prorated for each type of capacity, as well as the foreign exchange requirement, assuming percentages for foreign components as estimated for this study.

Table V.8: 1977-1990 CAPITAL EXPENDITURES FOR NEW POWER FACILITIES

U.S.$ Billions (1977)

	Foreign Component	Total	Foreign	
Hydro	50%	175.4	87.7	(32.8%)
Geothermal	60%	3.4	2.0	(0.8%)
Nuclear	80%	87.9	70.3	(26.3)
Thermal	60%	178.9	107.3	(40.1%)
Total		445.6	267.3	100.0%

The annual expenditures should increase from about $17 billion for 1977 to $52 billion (1977 dollars) for 1990.

It must be kept in mind that the above estimates are for capital expenditures for plant to be commissioned during the period 1977-1990. The total investment requirement for the period will be larger, since it will include capital expenditures for plant to be commissioned beyond 1990, interest during construction, financing charges and changes in working capital. Assuming that these additional funds amount to 30 percent of average annual requirements, the total power sector investment requirement for the period 1977-1990 for the 97 developing countries will be in the order of $580 billion, and the foreign exchange requirement will be about $350 billion.

F. System Size

Electricity costs in the smaller developing countries, including most of those in West Africa, are necessarily higher than in the larger countries because of their small system sizes. Large power systems provide economies of scale as a result of lower unit costs for generating equipment, reduced reserve generation capacity requirements, higher load factors, greater thermal efficiency, and larger scope for coordination of operation and maintenance because of the greater number of generating units in the system. For example, 30 MW steam units on a small system might cost $1,000/kW, compared to $600/kW for the 500 MW units that can be installed on large systems. Small systems with a few units may require 50 percent reserve capacity, compared to 20 percent for a large system having many units, because in the small system each unit represents a larger percentage of total system capacity. System load factors vary from 40 percent for a small rural system to 70 percent for a large system supplying a high percentage of industrial load. Large systems covering wide areas can exploit any potential for higher operational efficiency accruing from different timing of peak loads in different areas, the use of the most efficient generating stations to meet base load demands, and opportunities for thermal station support to the variable output of hydro stations.

G. Frequency Unification

The frequency of alternating current power supply in most countries in Europe, Asia and Africa is 50 Hertz (cycles per second) whereas the frequency in North, Central and most of South America is 60 Hz. Interconnecting power systems with different frequencies is expensive, since it requires the use of either rotating frequency converters or direct current converters/inverters. For this reason it is not usually attempted in practice. Those countries with dual frequencies consequently suffer a cost disadvantage because the frequency is not unified--for example:

(a) Liberia's public electricity supply is 50 Hz, but large U.S.-owned mining operations are 60 Hz, preventing inter-connection with potential for coordination of hydro and thermal sources.

(b) The frequency in Argentina is 50 Hz and in Brazil is 60 Hz. Interconnection would permit a large capacity saving due to the load diversity between the summer-peaking Brazilian and the winter-peaking Argentine systems. Future inter-connection could be facilitated by the Brazilian plan to use D.C. transmission for the Itaipu hydroelectric project.

(c) Saudi Arabia uses both 50 Hz and 60 Hz and will eventually unify the frequency to permit a national network. If 60 Hz is selected (as presently reported) interconnection with neighboring (50 Hz) Oman and the two Yemens will be expensive. The cost of frequency unification is high, and it increases as the system sizes involved grow in size themselves. Mexico carried out a frequency unification program in 1976 at a cost of around U.S.$160 million. Had this been done when the private power companies were nationalized in 1960, the cost would have been far less.

H. Combined Cycle Stations

One possibility for cost reduction in power generation is the use of combined cycle stations, i.e., gas turbines exhausting into waste heat boilers supplying steam generating units. This is a relatively recent development which holds considerable promise for the future. A typical configuration is composed of two 30 MW gas turbines and one 30 MW steam unit. The capital cost of combined cycle stations is lower and the thermal efficiency is better than for steam stations alone; however, combined cycle stations are complex and experience with them is limited. As "teething" troubles are eliminated and larger gas turbines, say 100 MW, are incorporated, this form of generating unit could become the standard for base-load operations in countries where relatively cheap natural gas is available for electricity production, for example, the Middle East oil producing countries.

I. Cogeneration

The use of cogeneration, whereby electricity and steam for industry are supplied jointly, and waste heat recovery have long been practiced in the industrialized countries of Europe, and to a much lesser extent in the United States. Opportunities are less obvious in developing countries because of limited requirements for space heating and process steam. However, in the future, industries such as textile and food processing plants in the developing countries might be able to effect significant fuel economies by the use of cogeneration.

J. Additional Energy Sources for Electrical Power Generation

As was noted in Chapter IV, huge quantities of gas produced in association with oil are still being flared in oil producing developing countries. For example, it has been estimated that the gas flared annually in Egypt is equivalent to the current annual rate of oil consumption for electricity production in that country's thermal plants. Similarly, Bahrain and Nigeria have been using nonassociated gas for electricity production while flaring associated gas. Most countries are now, somewhat belatedly, making some attempt to utilize associated gas at present wasted. The principal costs are in the low-pressure gas gathering system in the oil fields, the gas treatment plant, and construction of a gas pipeline or electrical transmission line to the energy demand centers. Where there is an appreciable industrial load to be supplied, it is probably that a gas pipeline will be more advantageous, since oil-fired boilers can be converted to gas with relatively minor burner charges. The utilization of natural gas, whether associated or non-associated, is subject to the constraints described earlier in Chapter III, and burning natural gas as fuel in thermal power stations is often used, in developing countries where it is available, as a means of building up demand to the point where a pipeline is economically justified.

The direct burning of wood in small power stations has been considered in some locations. However, this would only be justified in areas which are heavily forested, where transportation distance to the power station is short and where more productive lumbering or agricultural opportunities for the land do not exist. These conditions are somewhat unlikely to occur in conjunction with a large local demand for power. However, forest industry plants could make themselves energy self-sufficient in this manner.

Mill wastes include sugar cane bagasse, forestry and sawmill wastes, sawdust and the shells, pulp, husks and other materials that are often byproducts of wood and crop processing operations. In some cases, these materials are used productively and efficiently, but in many others they are wasted. In countries where these industries are important, the use of such wastes to make the industries concerned energy self-sufficient merits consideration. Most tropical plantation agriculture produces enough waste to supply a significant part of its energy needs if collection were properly organized.

The direct burning of heavy crude oil for electric power generation may be a possible fuel option for thermal plant in locations (e.g., the Caribbean) where heavy crude oil (10° to 13° API) is at present cheap compared with other fuels. The cost of Venezuelan heavy crude (11° API) was 15-20 percent lower than that of high sulfur residual fuel oil (in July 1979). New generating plants built to burn heavy crude rather than high grade fuel oil require more expensive boiler equipment to deal with the heavy metal content (particularly vanadium). The higher capital costs of plants burning this heavy crude must be weighed against lower present prices, and forecasts of future prices, when deciding between crude oil and fuel oil fired plants, although a plant originally designed to burn heavy crude could easily switch to fuel oil.

Decentralized small-scale hydro and wind-power systems may in future be considered as alternatives to conventional rural electrification systems where the resources are available. The cost of energy from small hydro installations in rural areas is unlikely to be low enough in most instances to allow power from them to be used for cooking, but they may be found competitive with the cost of bringing power to an area from an established electrical grid or generating it locally with small diesel sets. Mass production of standardized units could bring down the equipment cost, which at present is much higher than that of more conventional generating plant.

CHAPTER VI

ENERGY DEMAND MANAGEMENT, CONSERVATION, AND ENERGY PRICING

The present international energy situation and the outlook for the future have heightened awareness in all countries of the need for increased efficiency of energy utilization and for some kind of management of energy demand at the national level. This latter becomes most important in those countries which are endeavoring to shift away from imported petroleum and towards increased use of indigenous fuel resources. Energy demand management in turn requires a knowledge of what that demand may be in a country. Analysis of energy demand is, therefore, an essential tool for energy planning. Energy conservation is the counterpart to increasing energy production; it is frequently said that a barrel of oil saved is worth a barrel of oil produced (or imported, as the case may be). Energy pricing is an important policy issue in its own right, and is also an essential factor in energy demand management.

A. Energy Demand Analysis

Energy demand analysis is not an end in itself, but it is an essential requirement for intelligent energy planning and demand management. The analysis of energy demand can be made at the aggregated national level by computing the gross statistics of imports and domestic production, less exports (if any). In many of the poorer developing countries this is the most that can be attempted at present. Energy demand analysis becomes much more useful, however, if it can be made on the basis of sectoral consumption, and the sources and end uses of different energy forms identified.

A first-order sectoral breakdown which can be used for a primary analysis identifies energy use, both by quantity and type, for industry and manufacturing, commercial and services, domestic, and official sectors. End uses are broadly categorized as the transport of goods and people, space conditioning (heating, cooling, lighting), and materials processing (metal refining, food processing, cooking). Further disaggregation of the data is possible by means of more detailed information gathering; for instance, public transport can be separated from freight-hauling and private vehicle use; street lighting can be separated from interior lighting, and the latter in turn can be divided into domestic and commercial/industrial use. As the quantity of gathered information increases some form of data processing becomes essential.

Energy transformation functions are an important element in primary energy consumption. Both petroleum refining and thermal power generation come under this heading, and transformation losses are an important element of energy demand, amounting to between 5 percent and 10 percent of primary energy input in the former case and around 70 percent or more in the latter. Losses in the distribution system, both for liquid fuels and electric power, also need to be identified.

Energy consumption in rural areas, and of traditional fuels among urban populations, should be analyzed, including use of such items as crop wastes and animal dung. While these latter rarely enter into commerce, and almost always go unrecorded, in most developing countries they represent a substantial proportion of total energy consumption, as has been pointed out in Chapter I. The importance of this consumption to energy demand management is that it represents a potential demand for other forms of fuel which may suddenly emerge as a result of such factors as changes in the economy of the rural sector, or of demographic changes such as mass population migration from the countryside to urban areas. The quantity of wood fuel consumed, either directly or as charcoal, also provides a much-needed guide to the scale of effort required in forestry management and reforestation.

An essential counterpart to energy demand analysis is identification of the sources of energy supply, and whether these are of indigenous or imported origin. Energy sources need to be identified by type of primary or secondary energy used, i.e., whether a particular demand for fuel is met by burning petroleum distillates, coal, or traditional fuels, and whether these are interchangeable depending on availability and price. National production statistics for indigenous commercial fuels must also be obtained, together with estimates of internal consumption at the production stage and the amount of waste or loss; for example, the amount of associated natural gas flared, or the amount of coal lost or used in beneficiation.

Once the statistical data on energy supply and demand have been assembled, an energy balance can be struck for the economy as a whole, and if desired an econometric model can be constructed. The energy balance is usually fairly simple to construct and does not necessarily require data processing facilities. It is however, a "snap-shot" of a dynamic and changing situation, and will need regular updating at least every two years. Construction of an econometric model of the energy economy, on the other hand, is a relatively complex process requiring computer facilities and specially trained staff. It is useful for testing the effects of changes in basic parameters such as price and primary energy supply mix on the energy economy as a whole, and for forecasting trends and balance of payments effects. However, in practice, few computer models are sufficiently sophisticated to reflect accurately the operation of even a moderately industrialized economy, and the cost and effort of constructing them is unjustified in the case of a relatively undeveloped economy.

An interesting example of an energy balance for a developing country is that published by the Mexican Government in the monthly bulletin "Energeticos" from which Table VI-I is derived. One of the practical problems encountered in striking an energy balance is that of reducing all energy sources to a common dimension. This is usually expressed in heat units, but it may also be expressed as tons of coal equivalent or tons of oil equivalent, based on the relative calorific values of these fuels. A somewhat vexed question is how to show the value of hydroelectric energy in heat units. The heat equivalent of 1 kilowatt-hour is 3412 British Thermal Units (BTU), but if this direct conversion is used in the case of a country with a large hydro-power

Table VI-1: MEXICO: ENERGY BALANCE, 1977
(millions of barrels of oil equivalent)

Energy Source	Industry	Transport	Residential	Agri-cultural	Other	Non-energy	Petroleum sector	Electrical sector	Total
Coal	25.0							0.3	25.3
Fuel oil	41.6							45.9	87.5
Natural gas	45.6		3.6				38.1	11.0	98.3
Electricity	15.4		4.9	1.8	5.5				27.6
Gasoline		79.3							79.3
Diesel		63.6						6.2	69.8
Aviation fuel		7.3							7.3
Kerosene			12.2	2.0					14.2
Undifferentiated Petroleum products						17.8	28.3		46.1
Liquefied Petroleum gas			19.7						19.7
Hydro-geothermal								44.9	44.9
Electrical power distributed								(27.6)	(27.6)
Total	127.6	150.2	40.4	3.8	5.5	17.8	66.4	82.1	493.8

Source: Adapted from Comision de Energeticos.

component in its primary energy supply, or which imports electric power from a neighboring country, severe distortions result. It is therefore usual to use the thermal generation equivalent (i.e., the amount of fuel which would be needed to generate the same quantity of electrical energy in a thermal power plant) when constructing the energy balance. For rough comparative purposes this can be taken as three times the theoretical conversion, i.e., 10,236 BTU per kilowatt-hour. Greater accuracy is obtained if the overall conversion efficiency of the thermal generating system of the country concerned is used to make the conversion.

The problem of data gathering is one of the obstacles in the way of analyzing energy demand in a developing country. The lack of a sophisticated statistical reporting system usually means that staff must be specially trained for gathering energy consumption data. One possible method is to set up teams of intermediate grade statistical assistants who are provided with a standard questionnaire and each given a district or area to survey. In the case of industrial plants the number is usually not too great, and it is therefore possible to visit each plant individually, but in the case of the domestic and commercial sectors, especially in rural areas, it is necessary to establish some kind of random statistical sampling method. This can often be found ready-made in the form of a census base. Problems in data gathering often occur at the field level, since government officials armed with questionnaires are usually associated with tax assessments and the resulting misunderstandings may result in distorted information, or none at all. Another problem which arises in some countries is that of large seasonal variations in energy use. This may be due not only to space-conditioning requirements, but also to seasonal use in agriculture and food processing. The degree of detail required, and the density of sampling, are obviously a function of the degree of development of the energy economy, and the willingness of governments to allocate resources to what is often regarded as a non-productive activity. In a poor developing country, it is necessary to start with a very modest data-gathering and analytical program, probably involving a staff in the range of 5 to 15 persons altogether. The larger and more advanced developing countries would need a considerably greater staff and more advanced facilities to achieve a useful result. Effective energy planning must be a continuous activity, so the data gathering system can be progressively refined with time, as experience dictates. However, in the initial stages it is important to avoid gathering so much detailed information that it cannot readily be analyzed.

B. Energy Demand Management

The purpose of energy demand management is to reduce the consumption of energy per unit of GDP, and to control the growth of energy demand so as to reduce its overall cost to the economy, as for instance by fostering the use of indigenous energy sources to replace imported energy. Energy demand may be influenced in a number of ways, direct or indirect, short-term or long-term in their effects. Energy pricing is one of the most effective demand management tools. Other methods of influencing energy demand are administrative, such as rationing and allocation schemes; legal, such as the prohibition of certain energy-using equipment such as private power generators, automobiles of more than a certain horse-power; fiscal, by imposing discriminatory taxes on certain fuels or energy-using equipment. Differential import tariffs, variable electric power tariffs, and sales taxes on gasoline are commonly found fiscal measures used to manage energy demand. In some cases, the initial reason for imposing such taxes was to raise revenue for the government, and the energy demand aspect was neglected until recently. In the case of electricity tariffs, multiple rates are often initiated by utilities to reflect the cost of serving different classes of customers. However, it is not uncommon to find that the tariff systems of state-owned utilities have been modified to serve social or political ends. One of the commonly used, but least effective, methods of energy demand management is the appeal to public conscience for energy conservation in one form or another. While this may have an appreciable effect in the short term at a time of national crisis, it becomes less effective each time it is used and cannot be regarded as a substitute for more positive action over the long term.

Short-term measures for energy demand management seek to reduce existing inefficient and wasteful practices, such as excessive display lighting, automobile travel with no passengers, altering of thermostat settings in buildings. They are nearly all restrictive of consumption in some way, and in developing countries are often effective only on a very small proportion of total energy demand.

Long-term energy demand management seeks to reduce the growth of energy demand relative to GNP by such methods as: replacement of existing energy consuming equipment with new, more energy-efficient types; modification of older buildings and construction of new buildings to minimize energy consumption; changing energy consumption patterns from the use of imported fuels to using indigenous energy sources; planning industrial growth in accordance with availability or otherwise of indigenous energy sources.

To achieve these changes, the full range of methods available to governments should be used in a coordinated fashion. For example, if import duties are adjusted to favor the import of energy-efficient equipment, pricing policy should be used to reinforce this. Placing a high import duty on vehicles which are over-engined for their design has little effect if the corresponding fuels are still sold at low subsidized prices. In a developing country it is usual to find that legal and administrative methods of energy demand management are difficult if not impossible to enforce, so greater reliance should be placed on fiscal and pricing mechanisms. Pricing policy is probably the most flexible and effective method of energy demand management, but many governments are reluctant to use it vigorously because energy price increases invariably arouse serious social and political opposition.

Energy Demand in the Domestic Sector

In the majority of developing countries energy consumption in the domestic sector is primarily for cooking, with a small but important component for lighting. Only in the upper income brackets does energy consumption for space conditioning become a significant proportion of total consumption, with the exception of countries like Turkey and Afghanistan which have severe winter conditions. In analyzing energy consumption in the domestic sector, the following information is required:

(a) disposable income per household;

(b) number of persons in household;

(c) monthly electricity and fuel consumption, giving energy type, end use, quantity, and cost; and

(d) inventory of energy-consuming equipment in the household.

Apart from the obvious purpose of computing total energy consumption in the domestic sector, the information listed above permits the energy planner to calculate the effect of energy price changes on household income. In some developing countries lacking indigenous energy supplies, the proportion of household income expended on cooking fuel and light can be of the order of 30 percent among the urban poor, so that price increases become a serious issue.

Energy Demand in the Commercial and Service Sector

The information needed in this sector is basically the same as that required for the domestic sector, except that it is compiled on the basis of individual businesses and/or building units. Some problems of definition may be encountered, since at the upper end of the size range energy consumption may be of the same order as that of a small manufacturing unit. Since energy used for transport is important in this sector it is necessary to prevent double-counting if the transport sector is analyzed separately.

Energy Demand in the Industrial Sector

Industry is loosely classified into "heavy" and "light" segments. In general the heavy industries are very energy intensive, particularly those involving metal smelting. Table VI-2 gives representative energy requirements for producing a number of basic industrial raw materials. Some of these are of low intrinsic value, such as lime, cement, and brick; it is usually more economic for a developing country to buy the fuel (if it cannot be produced locally) and use the imported fuel to process local raw materials into products of this nature. In general, it is difficult, on economic grounds, to justify the establishment of the more energy-intensive industries in developing countries if both energy and raw materials have to be imported. The industiralized countries, notably Japan, are able to do this because they have the advantages of a large internal market for the product, economies of scale, advanced technology, and a highly skilled work force.

The analysis of energy demand in the industrial sector should be made by types of energy input and the nature of the energy form required, as follows:

Table VI-2: ENERGY REQUIREMENTS FOR HIGH PRIORITY PRIMARY PRODUCTS

Primary Product	Energy Required per net ton (short ton of product in millions of BTU)
Aluminum ingot	244
Quick lime	8.5
Portland cement	7.6
Common brick	3.5
Gaseous chlorine	18.0
Liquid chlorine	20.7
Cement copper	87.0
Refined copper	112.0
Glass containers	17.4
Steel slabs	24.0
Gray iron castings	34.0
Carbon steel castings	42.0
Refined lead	27.0
Gaseous nitrogen	2.9
Liquid nitrogen	8.1
Ammonia	39.0
Elemental phosphorus	172.0
Phosphoric acid	10.8
Basic brick	27.0
Fireclay brick, including ladle brick	4.2
Sulphuric acid (Frasch sulphur)	0.83
Sulphuric acid (weighted average for all raw materials)	0.04
Elemental zinc	65.0

Source: "Energy Use Patterns in Metallurgical & Non-metallic Mineral Processing - Phase 4 Energy Data and Flow Sheets, High Priority Commodities", by Battelle Columbus Laboratories, 1975. Report No. PB-245759.

Fuel Type	Output
Fuel oil	Low pressure steam (0-60 psi)
Natural gas	High pressure steam (250 + psi)
Coal	Low temperature heat (up to 150°C)
Lignite	High temperature heat (150+°C)
Electricity	Processing
	Motive power
	Space conditioning

Large complex modern plants should be encouraged to carry out their own energy audits, which are in principle the same as striking an energy balance for the country as a whole. The purpose is to study energy flows in the plant and to minimize losses. An energy audit of a medium-sized petroleum refinery (70,000 barrels per day) which resulted in a reduction in internal energy consumption and stock losses of 1 percent of throughput would save annually the equivalent of some 250,000 barrels of oil per year, which at $20 per barrel represents $5 million annually.

Small industrial plants would probably not be able or willing to carry out their own energy audits, but the aggregate energy savings possible might justify the setting up of an energy audit group within the energy planning organization.

C. Interfuel Substitution

An oil importing country which wishes to reduce oil consumption by substituting indigenous energy sources (unless these consist of domestically produced oil) is faced with a number of policy and investment decisions. In general, substitution between solid fuels is usually possible, but if the substitute fuel has a much lower calorific value than that originally used, then the output of the plant will probably be reduced below its design capacity. Substitution can take place in all sectors from the domestic to the industrial, but in some cases where the energy savings are marginal in absolute terms, the foreign exchange savings may still be sufficient to justify the change. One example is the substitution of solar water heaters for heaters using imported petroleum fuels in the domestic and commercial sectors. This usually requires a subsidy or tax rebate to cover the capital cost of the solar collector, but is nevertheless being encouraged in a number of energy-deficit developing countries.

Examples of physically feasible substitutions in the domestic and commercial sectors are as follows:

Original Fuel	Substitute
Wood	Wood waste pellets
	Smokeless coal briquettes
	Charcoal briquettes
	Peat briquettes

Original Fuel	Substitute
Kerosene	L.P.G. from natural gas processing
Electricity for heating	Solid fuels, solar energy

Some of these substitutions can be made directly, but most require investment either at the producing end, or by the consumer.

Fuel substitution in power generation is dealt with in Chapter V. In the industrial sector, most plants were constructed to burn fuel oil or gas oil. Conversion to burn natural gas is relatively easy and cheap, but conversion to solid fuels is rarely feasible even if the resulting loss in efficiency of the plant is acceptable. It is therefore necessary to rely on a long-term substitution as existing plant is replaced. Certain industrial processes are in any case fuel-specific and the contamination resulting from substituting solid fuel for a clean petroleum fuel would render the end product unacceptable.

D. Energy End Use in Transport

Energy for transport poses severe policy and planning problems for governments of developing countries. In the modern part of the transport economy of developing countries petroleum products provide the only primary energy source because the internal combustion engine still remains the most efficient form of prime mover. Alternative fuels such as alcohol are not readily available in the sizeable volumes required to substitute for petroleum products in transport, nor do they appear to be economically competitive even at present-day crude oil prices.

Table VI-3 shows the percentage of total petroleum product demand arising from transport use, while Table VI-4 shows the share of gasoline in petroleum product demand for transport use in a few developing countries. Table VI-3 shows that, except in Egypt and Korea, between 45 percent to 61 percent of total petroleum product demand in the mid-1970s was due to transport. Furthermore, the share of gasoline (in large part arising from private transport use) in the demand for petroleum products for transport varied from 43 percent to 63 percent for the countries given in the second table.

In analyzing the impact of energy policies on transport, it must be borne in mind that energy efficiency is not and cannot be the sole criterion for selection between one mode of transport and another: generally, the types of traffic handled by each mode of transport reflect the economic efficiency of that mode, in which energy efficiency is only one factor. Simple comparisons of the amount of energy consumed by different transport modes demonstrate wide variances in their energy efficiencies and considerable caution must be exercised in interpreting such results. For example, a large proportion of the travel by trucks, barges and rail cars occurs when the vehicles are empty.

Table VI-3: PERCENTAGE SHARES OF TRANSPORT IN TOTAL PETROLEUM PRODUCT DEMAND IN SELECTED DEVELOPING COUNTRIES

Country/Year	1966	1970	1971	1973	1974	1975	1976	1977
Brazil		60				61		
Thailand			45			45		43
India		49				59		
Colombia		54				57	56	
Egypt						21		
Tanzania				57				
Ecuador								58
Korea 1/	32				19			
Mexico						61		

1/ Note: Percentage share of the power sector in petroleum product demand was 9% in 1966 and 28% in 1974 and this change has contributed to the decline of the percentage share of transport in petroleum products demand between 1966-1974 in Korea.

Table VI-4: PERCENTAGE SHARES OF GASOLINE IN PETROLEUM PRODUCT DEMAND FOR TRANSPORT IN SELECTED DEVELOPING COUNTRIES

Country/Year	1960	1970	1971	1975	1977
Thailand			39	43	44
Brazil		56		55	
Mexico				52	
Colombia	81		58	63	

Therefore, tons shipped is only an effective measure of fuel efficiency when shipping densities are similar. For fuel efficiency comparisons, ton-miles-per-gallon values are useful when commodities of similar densities are involved; however, load size, vehicle type or mode and distance may vary.

The energy demands of various transport modes are given in Table VI-5. Though these data are average US figures, the technology is roughly similar worldwide and they should be approximately representative in developing countries. In interpreting these figures, however, the discussion in the previous paragraphs should be borne in mind.

Table VI-5: ENERGY INTENSIVENESS OF VARIOUS TRANSPORT MODES

Mode	Load Factor	Energy Intensiveness
		(BTU/per ton-mile)
Rail (diesel)	94%	750
Inland waterway	85%	500
Truck (diesel)	59%	2,400
Air cargo	65%	63,000
		BTU/passenger-mile
Small (US) car	2.2*	2,582
Standard (US) car	2.2*	4,323
Urban bus	30%	2,308
Air	50%	6,300

* Passengers per trip.

Whether the differences in fuel requirements are sufficiently important to determine the choice of transport modes can only be decided on a case-by-case, country-by-country basis. The relative cost differences between different transport modes in a given developing country may be so large that even substantial shifts in relative fuel prices are insufficient to alter the attractiveness of one compared with another. This issue is further complicated by the fact that taxes and distribution margins make up the major part of the end-user price of motor fuels, especially gasoline, in most oil importing developing countries.

The above discussion highlights the fact that in transport, energy policy issues are more complex than those encountered in the other sectors of energy demand. Two important transport energy policy issues arise -- pricing and physical limitation of demand.

Pricing Policy in Relation to Transport

Fuel prices in the transport sector should reflect the following factors: the desire to reduce consumption and improve the efficiency of use, true foreign exchange and opportunity costs of fuels, and the fact that fuel costs are a relatively minor proportion of total transport costs (see Table VI-6). Demand for gasoline among motorists appears relatively price-inelastic in the short term, which means that substantial and massive price increases are necessary to have any marked effect on demand. Even in those developing countries where such price increases have occurred, there is no clear evidence that consumption has declined although consumption growth rates may have been reduced. There is also evidence of inelastic demand for the services of road haulage industries, which means that diesel oil price increases are usually passed through to the consumer without a noticeable decline in fuel demand. Leaving aside the effect on public opinion, doubling of fuel costs leads to a relatively much smaller increase in overall transport costs, which implies that transport fuel costs should be kept at a relatively high level in order to restrain wasteful consumption, and as a revenue raising device.

Fuel costs in the UK in 1975 accounted for about 17 percent of the total cost of professional road haulage operations (based on diesel oil) and about 25 percent of private motoring costs (based on gasoline). Table VI-6 illustrates this. Substantial diesel oil and gasoline price increases would, therefore, lead to smaller but nevertheless significant increases in road haulage and motoring costs. Reference to Table VI-6 shows that doubling fuel costs would cause only about 20 percent increase in total vehicle operating costs. In the case of road haulage these increases will be passed on to customers. For that part of private motoring which is associated with business activity, gasoline price increases will also work their way back into retail prices. Despite the relatively minor effect of fuel price increases on transport costs, such increases are used by transport operators to justify disproportionate demands for tariff increases, and so are popularly regarded as being highly inflationary, despite the evidence to the contrary.

Table VI-6: FUEL COSTS IN PRIVATE MOTORING AND ROAD HAULAGE OPERATIONS IN THE UK (1975)*
(%)

Mode	Standing Costs	Fuel	Materials	Maintenance and Repairs	Vehicle Hire	Wages	Total
Road haulage	24	17 1/	9	3	2	45	100
Private motoring	60	24 2/	3	13	-	-	100

* From "Transport Policy and Energy", p. 133 of Proceedings of 6th International Symposium on Theory and Practice in Transport Economics, held in Madrid, Spain, 1977.
1/ Diesel oil; 2/ Gasoline.

Note: It is necessary to use statistics from the developed countries because data for developing countries are not available.

Despite the fact that fuel represents a relatively small proportion of total transport costs, it is both highly visible and one of the few operating costs which are under under the immediate control of the private vehicle owner. In consequence, increases in the price of vehicle fuels are invariably a sensitive political issue. In implementing energy policy, governments must be aware of the types of inter-fuel substitution which can nullify the desired shift in energy demand. If retail price differentials become sufficiently large between different fuels, some other fuel can be easily substituted by making only minor modifications in motor vehicle engines. For example, with slight modifications, LPG[1/] can substitute for gasoline in spark ignition engines, and kerosene can be used to adulterate for gasoline. This latter is common in those developing countries where kerosene and gasoline retail prices differ by as much as 300 to 500 percent. Kerosene can also be used to adulterate diesel fuel where the price differential is sufficient. The effect is to cause an increase in kerosene consumption relative to other petroleum products and destroy the balance of refinery output relative to market demand, in addition to causing the government heavy financial losses.

Physical Limitations on Fuel Demand in the Transport Sector

The purpose of all forms of rationing is to reduce consumption of fuel for activities considered inessential. Bans on weekend sales, mandatory limits on gasoline bought at a single time, or differentiation of purchasers on odd/even vehicle registration numbers are a form of rationing by inconvenience, but such policies are more eye catching than effective and are unlikely to lead to a significant reduction in fuel demand. A full rationing scheme can lead to substantial decreases in fuel demand, but requires a sophisticated administrative and enforcement machinery which is probably beyond the capacity of most developing countries. The basic argument for rationing is that everyone is assured at least a minimum amount of fuel at a regular price. It is therefore free of some of the income distribution objections which arise from a strict pricing policy approach. Among the disadvantages of a rationing system are the difficulties of allocating supply between sectors of the economy and the fact that all rationing systems ultimately give rise to a "black market" in the commodity concerned. In most developing countries, therefore, demand restraint in the transport sector is more easily achieved by pricing policy than by physical restraints.

Diesel Fuel vs. Gasoline

Though the diesel engine has a higher thermal efficiency than the gasoline engine in larger sizes, in the small horsepower range (below 100 horsepower) it is both heavier and more costly than a comparable gasoline engine without being appreciably more efficient. Replacing automobile gasoline engines by diesel engines will only bring about a very modest reduction in fuel consumption at best, especially in urban traffic. The benefits are

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1/Liquified petroleum gases. This could be particularly attractive for those developing countries producing indigenous natural gas but not oil.

more apparent in the higher horsepower ranges. Table VI-7 shows comparative characteristics of a 200 horsepower vehicle for different combustion cycles. In making comparisons between the efficiency of spark ignition engines and diesel engines, it is necessary to take account of the difference of specific gravity between the two fuels; most comparisons are made on a miles per gallon basis since this is the basis on which the fuels are sold, and this gives an automatic bias in favor of the diesel, since a given volume of diesel fuel contains more thermal energy than does a corresponding volume of gasoline. But when the comparison is made on the basis of thermal efficiency and weight of fuel consumed (as in Table VI-7), there is little difference between gasoline and diesel engines in the small horsepower range. The wholesale prices of gasoline and diesel fuel at the refinery are more or less the same; the wide price differential the consumer often finds is due to heavy taxation of gasoline, not to differences in production costs.

A final transport energy policy issue that needs to be addressed is the possible role of ethanol (ethyl alcohol) as a fuel in the transport sector as a partial substitute for gasoline and diesel oil. Ethanol/gasoline fuel mixtures can be used in motor vehicles without any engine modifications for ethanol admixtures of up to about 15 percent by volume. At higher percentages of ethanol (up to 100%) engine modifications are required. Several oil importing developing countries presently have rather large sugar industries and ethanol can be produced either from molasses or directly from the cane juice. Production of ethanol from cassava, or grain, or any crop containing appreciable quantities of starch or sugar, is also technically possible.

The economics of ethanol production for use as a fuel in transport in oil importing developing countries must be carefully examined on a case-by-case basis, particularly as it involves issues related to the optimal use of agricultural land in a developing country. The first factor to be recognized is that the land area requirements for a major ethanol fuel program are very large. For example, in order to effect a 100 percent substitution of 1,000 barrels/day 1/ of gasoline by ethanol would require between 23,000-100,000 hectares 2/ of land under sugarcane production. The true cost of producing ethanol as fuel is not simply the cost of sugar, which is at present very low, but also depends upon the value of alternative crops which could be grown on good agricultural land (as is needed for sugarcane production). In addition, the true production cost of alcohol has to be measured against the import parity price of gasoline, which for several regions of the world is presently between 80 and 90 US cents per US gallon. Waste disposal of liquor from the stills can produce serious pollution problems owing to the large quantities involved—about 5.5 barrels for each barrel of alcohol produced.

1/ One US barrel equals 42 US gallons or 159 liters.

2/ The lower limit would occur if the alcohol is directly produced from cane juice while the upper limit would arise if the molasses route is taken with associated sugar production. It is assumed that 50 tons of cane are produced per hectare.

Table VI-7: CHARACTERISTICS OF A 200 HORSEPOWER VEHICLE FOR DIFFERENT COMBUSTION CYCLES *

Category	Internal Combustion Reciprocating Piston	Internal Combustion Rotary Wankel Piston	Diesel	Gas Turbine	Steam	Stirling
Cycle	Otto	Otto	Diesel	Brayton	Rankine	Stirling
Fuel	Gasoline	Gasoline	D. Oil	Many	Many	Many
Thermal Efficiency, %	32%	30%	35%	30%	28%	40%
Specific Weight, lbs/H.P.	3	2	4	2	7	8
Specific Volume, cu. ft/H.P.	0.055	0.02	0.07	0.08	0.14	0.18
Specific Fuel Consumption lbs/H.P. hour	0.4	0.4	0.4	0.45	0.5	0.35
Specific Cost** $/H.P.	3	4	5	5	4	6

* Data from Mitre Corporation.
** In 1972.

Methyl alcohol (methanol) can be used in place of or mixed with ethanol. It is produced by pyrolysis of wood, as in charcoal manufacture, or can be synthesized from natural gas, or from synthesis gas produced from coal. It is much more expensive than gasoline at present and has several technical disadvantages, not the least of which is its capacity to absorb water and to corrode the fuel system of a conventional automobile.

E. List of Possible Energy Conservation Measures 1/

A list summarizing the possible energy conservation measures which should be included within any program of energy demand management is given below. Those measures specific to energy end use in transport are not included in this list since they have been discussed above.

(a) The most critical elements of an energy conservation program are the levels of energy prices and energy taxes. Prices of all primary energy supplies to the end user should be at world market levels at least. Until governments of oil importing countries act to raise petroleum prices in particular to the international level, they are unlikely to be regarded as taking a serious view of energy conservation.

(b) Significant energy taxes should be imposed on certain fuels to reinforce the effects of market prices. This is particularly the case for gasoline. However, the problem should be borne in mind of not allowing price differentials of liquid fuels which are easily substitutable one for another to become too great.

(c) A comprehensive public education program on the need for energy conservation should be launched by government. This program will have to be sustained over a two-year period at least.

(d) Full-time government energy conservation staff must be available to monitor and coordinate the program. This would include the training of specialized personnel such as energy auditors.

(e) Conservation programs need to be drawn up to increase the use of waste heat from electricity generation and utilization of combustible waste from industrial processing.

1/ "Energy Conservation in the International Energy Agency, 1976 Reviews," published by the OECD.

(f) Lighting and thermal efficiency standards need to be introduced in new commercial and public buildings and residences through changes in building codes and practices, especially as most modern buildings of any size have not so far been designed with energy efficiency in mind. Building insulation is important in hot climates to reduce air conditioning loads.

(g) Financial incentives need to be established to stimulate modification of existing residences and commercial buildings and to improve lighting and thermal efficiencies.

(h) Energy efficiency labelling for all major consumer appliances needs to be made mandatory.

(i) Programs to increase energy efficiency in industrial production need to be formulated and implemented. Conservation targets should be set. Loans provided for energy improvements, tax credits, rapid depreciation allowances, and execution of energy audits are elements of such a program.

(j) Policies and programs to improve the efficiency of electricity generation (peak load pricing, for example) need to be formulated and implemented, as well as for electricity transmission and distribution.

(k) Changes in electrical utility marketing practices and price structures should be undertaken to reward conservation by customers, and to discourage energy-inefficient uses such as electric heating devices and cookers.

F. Financing Energy Conservation

The economic and financial returns on energy conservation investments at present prices are generally high, with associated rapid payouts. Despite the attractiveness of these investments, experience in developed countries has shown that government-stimulated financial incentives are an important ingredient in carrying out a major energy conservation program. Financing for the program can be provided from part of the revenues obtained from energy taxes.

G. Energy Pricing Policy

Energy pricing policy is at the core of a country's overall energy policy. It is directed at a series of related issues such as:

(a) What should be the relationship between the prices of primary energy fuels such as coal, crude oil and natural gas charged to power utilities? And what relationship should these prices bear to those charged to the producers?

(b) What should the relationship be between the prices of petroleum products (LPG, gasolines, kerosenes, diesel and fuel oils) at the ex-refinery price level, as well as at the retail price level?

(c) What implications does a specific energy pricing regime have for the future market shares of primary energy fuels and secondary energy supplies (such as electricity) in the total energy supply mix?

(d) At what rate should indigenous nonrenewable energy resources in developing countries be depleted and does the price applied to any given resource satisfy the depletion rate objectives?

(e) What should the relationship be between the prices of competing fuels at the end-point of consumption, e.g., between charcoal, LPG, kerosene, natural gas and electricity for domestic cooking; between gasoline, diesel oil and LPG as fuels for transport; between coal, fuel oil, and natural gas for thermal power generation?

(f) Should energy prices be used as a mechanism to achieve income distribution objectives in a society? If so, how?

The complexity of the above questions is such that answers can only be provided in a country-specific setting. Despite this, guidelines can be used to delineate the appropriate range of prices of primary nonrenewable fuel resources, such as coal, crude oil or natural gas.

(a) The delivered price should not be higher than the economic costs of the next best alternative fuel delivered to the particular intermediate user -- usually a power utility company or large industrial consumer in the cases of coal, natural gas and residual fuel oil.

(b) This delivered price should not be higher than the net financial costs of alternative fuels, unless the user is a government entity subject to government directives, in which case only the economic constraint applies. 1/

(c) The delivered price of the fuel should not be less than its full marginal economic cost of supply.

1/ Both economic and financial costs should be adjusted to account fully for quality differences of alternative fuels and the associated differences in capital, as well as operation and maintenance costs of equipment, required to utilize these alternative fuels.

(d) The fuel price should not be lower than its highest economic value in its next best alternative use now or in the future.

(e) The revenues derived from the sales of fuel should be adequate to cover the producing entity's full accounting costs, including depreciation, and a sufficient return on capital to keep energy producing entities financially viable, including the need to carry on exploration for new resources.

The issue of reflecting future scarcity of particular fuels into present prices for these fuels becomes of some significance. This is particularly so in those developing countries where the indigenous energy resource base of particular fuels is very limited relative to present and future demand, and the country faces, upon depletion of a given resource, the need to enter the international market to purchase energy to replace it, at a time when the international availability of fuels may be constrained and prices higher than that previously charged for the domestic resource.

Some developing countries have taken positive steps since 1973 to adjust their liquid fuel prices to international levels. However, oil exporting developing countries (both OPEC and non-OPEC members) and some oil producing but non-exporting countries still tend to sell petroleum products in their domestic markets at prices well below international levels. Table VI-8 illustrates the differences in retail gasoline and Bunker C fuel oil

Table VI-8: RETAIL PRICES OF GASOLINE AND RESIDUAL FUEL OIL IN SELECTED DEVELOPING COUNTRIES 1/

Country	Retail Prices of Regular Gasoline US cents/US gallon		Retail Prices of Residual Fuel Oil US$/Barrel	
	July 1976	July 1977	July 1976	July 1977
Brazil	150.7	151.2	7.31	13.51
Colombia	21.1	27.4	6.05	15.69
India	142.4	142.4	11.32	12.83
Indonesia	63.8	63.8	8.42	8.42
Iran	32.2	45.6	10.91 2/	2.69 3/
Kenya	109.0	125.0	11.76	N.A.
Mexico	65.0	46.0	9.70	N.A.
Philippines	71.0	84.8	16.38	16.95
Saudi Arabia	11.8	11.3	2.52	2.60
Thailand	76.8	73.3	13.52	12.61
Venezuela	13.8	13.2	0.67	3.18

1/ Source: IBRD. N.A. = Not available.
2/ Price to international vessels.
3/ Price to domestic users.

prices in 11 developing countries, four of which are OPEC members and one a net oil exporter non-member of OPEC. What this table highlights is a widening gap in petroleum product prices among developing countries dependent on their petroleum resource endowment.

A comparative analysis of retail prices of regular and premium gasoline, kerosene, diesel oil and residual fuel oil in July 1973 and July 1977 for 30 developing countries is presented in Table VI-9 As can be seen the annual rate of increase of individual petroleum product prices between 1973-1977 varied drastically among products and countries.

Generally speaking, products for direct consumption, such as gasoline, are taxed more heavily than those for intermediate uses, such as fuel oil. In the case of petroleum products such as kerosene, which are mostly consumed by low income rural (for lighting) and urban (for cooking and lighting) households in developing countries the level of taxes usually applied to such products is either very low, or there may be direct subsidies provided by the government. Table VI-10 shows the taxes on regular and premium gasoline, kerosene, diesel and residual fuel oils in July 1973 and July 1977 for 30 developing countries. Since this difference in taxation gives rise to wide price differentials, it inevitably stimulates substitution of expensive fuels by cheaper ones at the consumer level. One result has been a disproportionate rise in kerosene consumption in many developing countries.

From this table it can be seen that in 1977, Bolivia, Burma, Colombia, Jamaica, Mexico, Pakistan, Peru, Sri Lanka and Tunisia were subsidizing household kerosene by selling it below world price levels on the domestic market. Of these developing countries only Jamaica and Sri Lanka are not oil or gas producers. When one turns to the gasoline market, in 1977, Bolivia, Burma and Colombia were in effect subsidizing regular gasoline sales on the domestic market by selling it below world price levels. All of these three countries are oil and/or gas producers. No non-oil or gas producing developing countries (among those included in the same of 30 countries) were subsidizing gasoline sales in 1977.

Direct subsidies applied to specific liquid fuels -- no matter how justified socially -- introduce severe distortions in petroleum product demand patterns and give rise to abuses as well as interfuel substitution, since many items of energy consuming equipment can easily switch fuels, especially if the financial incentive to do so is high. For example, with slight modifications a gasoline/kerosene admixture can be used in motor cars, kerosene can be mixed with diesel fuel, and with adjustments LPG can substitute 100 percent for gasoline in transport use. When the retail prices of kerosene and gasoline are permitted to differ by as much as 300 to 400 percent then it is inevitable that kerosene will be diverted to other uses than the one originally intended to be subsidized.

Energy pricing can play a considerable role in accelerating exploration for and development of primary fuels. Finally, several of the energy producing entities in developing countries are state owned and are

Table VI-9 : RETAIL PRICES OF PETROLEUM PRODUCTS PRIOR TO AND POST 1973 OIL EMBARGO - DEVELOPING COUNTRIES

(in US¢/gallon, except residual fuel oil in US¢/42-gallon barrel)

Countries	Regular Gasoline/1				Premium Gasoline				Household Kerosene				Diesel Fuel Oil				Residual Fuel Oil			
	1973, July	1977, July	% Growth 1973-77	1977 World Price as % 6f 1977 Domestic Price	1973, July	1977, July	% Growth 1973-77	1977 World Price as % of 1977 Domestic Price	1973, July	1977, July	% Growth 1973-77	1977 World Price as % of 1977 Domestic Price	1973,/1 July	1977, July	% Growth 1973-77	1977 World Price as % of 1977 Domestic Price	1973, July	1977, July	% Growth 1973-77	1977 World Price as % of 1977 Domestic Price
Argentina, Buenos Aires	60.4	82.6	8.1	47	71.8	100.9	8.9	43	34.0	45.9	7.8	83	45.9	39.0	-4.2	97	390.4	728.8	16.9	165*
Bolivia, La Paz	17.0	27.8	13.1	140*	26.0	64.9	25.7	67	6.0	5.6	-1.7	684*	10.0	24.1	24.6	158*	336.0	856.8	26.4	140*
Brazil, Rio de Janeiro	29.2	151.2	50.8	26	37.8	185.2	48.8	23	27.2	83.2	32.2	46	39.8	83.2	27.9	46	235.1	1351.4	54.8	89
Burma, Rangoon	43.3	40.8	-1.5	103*	48.4	175.0	37.9	27	20.8	29.2	8.9	142*	20.7	29.2	9.0	133*	398.8	840.0	20.5	148*
Chile, Santiago	56.7	90.7	12.5	43	170.1	117.2	-9.8	37	37.8	52.9	8.8	72	4.0	75.6	108.5	50	920.2	2540.2	28.9	47
Colombia, Bogota	14.3	27.4	17.7	142*	19.3	36.9	17.6	118*	12.6	26.1	20.0	147*	12.0	50.0	42.9	76	399.0	1596.0	41.4	75
Dominican Rep., S. Domingo	47.0	0.0	-728.0	388*	61.0	99.0	12.9	44	36.0	75.6	20.4	51	32.0	52.8	13.3	72	961.8	1959.3	19.5	61
El Salvador, S. Salvador	52.0	97.6	17.0	40	55.6	103.2	16.7	42	18.0	64.0	37.3	60	24.0	44.0	16.4	86	403.2	1438.5	37.4	84
Ethiopia, Addis Ababa	89.5	121.3	7.9	34	96.6	142.1	10.1	32	68.8	82.0	4.5	49	65.3	82.0	5.9	44	354.4	1302.0	38.4	88
Ghana, Accra	54.2	101.5	17.0	41	58.8	145.0	25.3	31	29.2	72.5	25.5	56	25.4	72.5	30.0	49	1084.0	2375.1	21.7	48
India, New Delhi	71.2	142.4	18.9	29	73.7	149.1	19.3	30	30.7	54.6	15.5	74	43.4	56.3	6.7	64	413.3	1282.9	32.7	89
Jamaica, Kingston	37.6	171.7	46.2	23	45.5	180.8	41.2	24	14.7	32.0	21.5	120*	16.0	48.0	31.6	79	453.6	1270.0	29.4	95
Kenya, Nairobi	59.0	125.0	20.6	33	63.9	130.0	19.4	35	33.3	69.0	20.0	59	28.5	89.0	32.9	40	806.2			
Lebanon, Beirut	47.0	73.0	11.6	57	54.0	85.2	12.1	53	29.0	54.8	17.2	74		36.5		98		1022.3		112*
Mexico, Mexico City	24.2	46.0	17.4	80	33.3	66.0	18.7	59	10.3	9.0	-3.4	394*		10.0		380*	300.0			
Morocco, Rabat	89.3	160.0	15.7	26	93.2	180.0	17.9	25	43.7	65.0	10.4	62		65.0		55	590.8	1000.8	14.1	115*
Pakistan, Islamabad	50.8	108.0	20.8	38	55.0	116.0	20.5	39	16.7	31.0	16.7	131*	25.3	54.0	20.9	66	423.5	895.6	20.6	128*
Panama Rep., Panama	46.8	100.0	20.9	39	50.3	110.0	21.6	40	22.0	50.1	22.8	76	21.0	50.0	24.2	76		1621.0		74
Paraguay, Asuncion	57.0	150.0	27.4	26	81.0	180.0	22.1	24	42.0	78.0	16.7	49	38.0	78.0	19.7	49	1008.0	2268.0	22.5	53
Peru, Lima	21.0	93.0	45.1	42	35.0	136.0	40.4	32	4.0	12.0	31.6	319*	15.0	21.0	8.8	181*	470.0	504.0	1.8	238*
Philippines, Manila	18.0	84.8	47.3	50	22.0	92.5	43.2	51	16.0	57.2	37.5	73	15.0	61.8	42.5	63	420.0	1694.7	41.7	73
Portugal, Lisbon	84.6	177.6	20.4	20	99.5	207.2	20.1	19	30.4	45.4	10.5	87		59.2		65	405.3	905.1	22.2	133*
Singapore, Singapore	88.0	107.0	5.0	39	94.0	119.8	6.3	39	91.0	52.2	-14.9	80	20.0	41.6	20.1	94	581.0	1508.2	26.9	82
Spain, Madrid	78.3	139.0	15.4	26	98.7	179.0	16.0	22	34.0	72.0	20.6	55		52.0		74	446.0	1112.0	25.7	108*
Sri Lanka, Colombo	71.7	146.7	19.6	28	77.5	152.5	18.4	30	17.5	40.0	23.0	101*		60.3		59	371.6	2111.6	54.4	54
Thailand, Bangkok	39.0	73.3	17.1	57	43.0	78.7	16.3	60	36.0	50.0	8.6	83	19.9	49.2	25.4	79	504.0	1260.8	25.8	98
Tunisia, Tunis	161.0	155.5	-0.9	27	168.3	164.7	-0.5	27	65.9	36.6	-15.8	111*		85.4		42	405.4	2252.3	53.5	51
Turkey, Ankara	41.7	58.0	8.6	71	55.0	71.8	6.9	63	36.2	52.4	9.7	77		51.9		69	770.0	1118.0	9.8	103*
Uruguay, Montevideo	85.0	157.0	16.6	25	108.0	199.0	16.5	22	30.0	84.0	29.4	49	25.0	72.5	30.5	52	588.0	1554.0	27.5	77
Yugoslavia, Belgrade	72.0	140.0	18.1	26	78.0	146.0	17.0	26	36.0	59.0	13.1	67		88.0		44	252.0	1201.0	47.8	100*

* Implicitly, this petroleum product is subsidized since it is priced below the world price.

Table VI-10: TAXES ON PETROLEUM PRODUCTS PRIOR TO AND POST 1973 OIL EMBARGO

DEVELOPING COUNTRIES

(in US¢/gallon, except residual fuel oil in US¢/42-gallon barrel)

Countries	Regular Gasoline			Premium Gasoline			Household Kerosene			Diesel Fuel Oil			Residual Fuel Oil		
	1973, July	1977, July	% Growth 1973-77	1973, July	1977, July	% Growth 1973-77	1973, July	1977, July	% Growth 1973-77	1973, July	1977, July	% Growth 1973-77	1973, July	1977, July	% Growth 1973-77
Argentina, Buenos Aires	44.7	65.2	9.9	53.1	80.9	11.1	14.2	21.0	10.3	20.9	17.3	-4.8	65.5	191.3	30.7
Bolivia, La Paz	4.0	2.8	-9.3	5.0	6.4	6.4	0.0	0.6	178.3	0.0	2.4	293.6	0.0	84.8	859.6
Brazil, Rio de Janeiro	9.7	37.8	40.5	1.1	52.9	163.3	3.9	7.6	18.2	11.8	11.3	-1.1		0.0	
Burma, Rangoon	24.2	2.5	-76.4	24.2	25.9	1.7	0.8	1.7	20.7	4.3	1.7	-26.1	8.8	70.0	67.9
Chile, Santiago	23.6	37.8	12.5	63.2	52.9	-4.5	3.1	5.3	14.3	0.6	22.7	148.0	92.0	476.3	50.8
Colombia, Bogota	4.2	6.2	10.2	5.2	15.3	31.0	0.2	0.1	-18.9	4.0	0.0	-347.2	0.4	42.0	220.1
Dominican Rep., S. Domingo	18.7	0.0	-557.6	18.7	40.3	21.2	14.7	14.7	0.0	6.0	5.5	-2.2	390.6	389.8	-0.1
El Salvador, S. Salvador	25.7	54.1	20.5	25.7	54.1	20.5	0.0	0.1	77.8	3.2	2.6	-5.3	29.4	30.7	1.1
Ethiopia, Addis Ababa	43.8	22.7	-17.9	43.8	28.4	-11.4	34.9	12.9	-28.3	37.5	15.1	-25.5		0.0	
Ghana, Accra	28.8	25.1	-3.5	28.8	63.0	21.6	1.2	13.1	81.8	9.4	15.7	13.7	470.6	608.7	6.6
India, New Delhi	49.3	92.8	17.1	49.5	93.2	17.1	12.2	18.9	11.6	23.0	19.7	-3.9	49.3	57.7	4.0
Jamaica, Kingston	13.6	110.7	68.9	16.6	115.1	62.3	0.0	0.0	-	0.0	0.0	-	0.0	0.0	-
Kenya, Nairobi	31.3	55.0	15.1	31.3	55.0	15.1	7.2	6.0	-4.7		23.0		0.0		
Lebanon, Beirut	31.0	25.1	-5.4	31.0	25.1	-5.4	14.0	11.2	-5.7		2.0			56.3	
Mexico, Mexico City	4.5	15.0	35.1	5.4	22.0	42.1	1.6	0.0	-255.7		0.0		33.6	0.0	-661.4
Morocco, Rabat	53.0	103.5	18.2	52.2	114.7	21.8	20.0	24.9	5.6		24.6		99.7	198.0	18.7
Pakistan, Islamabad	37.5	61.0	12.9	37.5	46.0	5.2	5.0	23.0	46.5	11.4	39.0	36.0	87.5	558.6	59.0
Panama Rep., Panama	13.7	43.2	33.3	13.9	50.5	38.1	15.3	1.7	-73.2	0.0	2.0	276.1		1512.0	
Paraguay, Asuncion	20.0	24.0	4.7	25.0	28.0	2.9	9.0	7.0	-6.5	7.0	5.0	-8.8	210.0	168.0	-5.7
Peru, Lima	8.0	31.0	40.3	16.0	43.0	28.0	0.2	0.6	31.6		1.0			29.4	
Philippines, Manila	5.2	25.5	48.8	5.2	28.1	52.5	2.1	3.6	14.4	0.0	8.9	446.2	30.2	96.6	33.7
Portugal, Lisbon	59.7	118.8	18.8	71.0	142.3	19.0	5.7	22.9	41.6		8.1		144.1	259.5	15.8
Singapore, Singapore	56.0	112.6	19.1	56.0	108.2	17.9	8.0	3.8	-20.5	2.8	0.0	-309.1	93.1	189.8	19.5
Spain, Madrid	39.3	34.0	-3.7	42.5	38.0	-2.8	9.1	6.0	-11.0		6.0		4.5	0.0	-360.6
Sri Lanka, Colombo	31.0	26.4	-4.1	33.5	27.5	-5.1	5.0	3.2	-11.8		4.9		0.0	144.6	996.6
Thailand, Bangkok	16.1	26.8	13.6	16.3	27.0	13.4	7.5	6.2	-4.9	3.1	6.2	18.9	50.0	0.8	-181.2
Tunisia, Tunis	73.7	238.1	34.1	77.3	251.0	34.2	18.8	27.4	9.9		47.2		0.0		
Turkey, Ankara	25.3	22.9	-2.5	36.4	31.7	-3.5	17.2	16.6	-0.9		18.8		202.0	209.0	0.9
Uruguay, Montevideo	42.0	64.0	11.1	57.0	87.0	11.2	4.0	11.0	28.8	6.1	13.5	22.0	168.0	168.0	0.0
Yugoslavia, Belgrade	42.0	91.0	21.3	47.0	94.0	18.9	22.0	22.0	0.0		37.0		0.0	676.0	1512.5

unsound financially because of government pricing policies. This is primarily because they are not permitted to charge tariffs or prices which are sufficiently high to enable them to recover the cost of providing services to their customers, as well as to accumulate sufficient financial surpluses to pay for expansion and/or exploration for new resources. The results are poor service to the consumer and, ultimately, supply shortages.

Increases in crude oil prices over the last six years have been accompanied by increases in steam coal and uranium prices. Table VI-11 shows historical prices (1972-1976) of steam coal in certain producer countries as well as values at the major importing points in the world. It can be seen from this table that steam coal prices have increased two to three times in current dollars over the period 1972-1976. It remains to be seen whether coal prices on the international market will move towards the prices set by international fuel oil prices. However, the differential between coal and oil prices at present is sufficient to justify serious consideration of coal development or imports as a substitute for fuel oil.

Table VI-11: HISTORICAL COAL TRADE VALUES FOR SELECTED COUNTRIES (1972-76)

(US$/metric ton)

Producing Countries:	Australia			Poland			Canada		
Year	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif
1972	6-9	20	18	-	22-24	24	-	13	21
1973	7-9	18-22	20	-	22-25	24	13	-	22
1974	16-17	26	30	-	32-39	39	-	14	31
1975	16-26	40	39	-	42-57	57	18-32	36	48
1976	14-31	45-48	51	-	36-59	59	20-33	-	58

Producing Countries:	F. R. of Germany			Mozambique			South Africa		
Year	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif
1972	23-37	31-55	-	-	-	17	-	7	19
1973	24-39	36-37	-	-	-	-	-	24	18
1974	44-50	42-44	-	-	-	37	-	30-40	34
1975	59-64	54-65	84	-	-	47	15	28-50	43
1976	72	44-70	-	-	-	43	21	30-32	41

Producing Countries:	United Kingdom			USSR			USA		
Year	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif	fob	W. Europe cif	Japan cif
1972	-	12-35	-	-	14-18	21	21	23-30	29
1973	-	12-29	-	-	14-17	21	23	24-29	30
1974	-	37-44	-	-	19-32	33	48	42-53	63
1975	29-41	40-56	-	-	30-58	50	59	50-73	73
1976	32-46	44-53	-	-	32-48	52	58	48-59	68

Notes: (1) All values have been calculated on a tonnage basis without consideration of quality differences.

(2) fob = free on board value at the port of export, based on the transaction price including packing, inland freight, dock delivery, loading charges and other expenses up to the point where the merchandise is deposited on board the exporting vessel.

(3) cif = cost, insurance and freight delivered at the port of entry; values for Japan include only bituminous exports (mostly coking coal), while those for Western Europe include both bituminous coal and anthracite.

Sources: World Coal Trade, 1973-75; International Coal (formerly World Coal Trade), 1976-77; Commodity Trade and Price Trends, IBRD, 1978.

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