Discussion Paper D-73C
ENERGY IN DEVELOPING COUNTRIES SERIES

Factors Affecting the Composition of Energy Use in Developing Countries

Joy Dunkerley, Gunnar Knapp
with Sandra Glatt

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The views expressed in this paper are those of the authors and should not be interpreted as representing the views of either A.I.D. or Resources for the Future.

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INTRODUCTORY NOTE

Energy consumption in developing countries has been rising rapidly and substantially faster than in developed countries. All indications are that continued growth in energy use will accompany any success such countries have in improving living standards for the rest of this century and beyond. This pattern of energy demand growth stands out even more clearly when the commercial fuels alone are considered.

Among the commercial fuels, oil has a special place in developing countries. It is the most versatile of the energy sources, it tends to require the least infrastructure to bring to bear in doing useful work, and in a context of scattered and small scale applications, user capital per unit of work delivered is relatively low.

These generalizations have gained wide acceptance, and to the extent they are true, their implications are important:

- Developing countries will be placing greater and greater demands on world fuel supplies, especially oil, contributing to upward pressures on oil prices.

- Rising prices of oil will seriously hinder economic growth and consumption in developing countries.

- There is an incentive for developed countries to assist developing economies in their efforts to conserve energy--to foster substitution for it of other (now relatively cheaper) factors of production.

- And similarly, substitution of other energy sources, both traditional and commercial, for oil may be in the interest of oil importers (if not oil exporters) everywhere.

"Factors Affecting the Composition of Energy Use in Developing Countries" offers insight on the potential for substituting other energy sources for oil. In identifying the factors which influence oil use, by inference Joy Dunkerley and Gunnar Knapp also suggest points at which intervention to restrain it may be more or less effective and more or less costly. Analysts and policy makers with responsibility for developing country energy policies will find much here to consider when deciding on such intensely practical questions as the prospective returns to new hydro projects or the wisdom of different levels of subsidies to kerosine.

This study is an outgrowth of ongoing work on energy and developing countries at Resources for the Future. It was funded by the Agency for International Development under the ARDEN (A.I.D.-RFF Development and ENergy) Cooperative Agreement No. AID/DSAN-CA-0179.

The analysis of energy use patterns by form and source reported on here represents a further development of the analysis contained in Energy Strategies for Developing Nations (Baltimore: Johns Hopkins University Press for Resources for the Future, 1981) by Joy Dunkerley, William Ramsay, Lincoln Gordon and Elizabeth Cecelski and is a companion to two earlier studies "Industrial Energy Demand and Conservation in Developing Countries" by John E. Jankowski, Jr. (RFF Discussion Paper D-73A) and "Interfuel Substitution in the Indian Economy" by Ashok V. Desai (RFF Discussion Paper D-73B).

We issue this report on work in progress with the multiple purposes of informing the policy community of the state of knowledge, of stimulating research elsewhere, and of eliciting comments on our own efforts.

Milton Russell
Director, Center for
Energy Policy Research

Chapter 1

INTRODUCTION

The radical changes in energy prices since 1973 are likely to have significant effects upon the composition of energy use in developing countries. Although there have been major fuel substitution cycles in the past--of wood by coal and coal by oil--the nature of this process is not well understood. Little has been done to evaluate the lessons of this past experience with a view to providing guidance for the future.

In developing countries, the problem of effecting changes in the composition of commercial fuel supplies is compounded by structural changes in their economies as development takes place. Typically, as income rises, agriculture and industry become more mechanized, relative prices or availabilities of traditional fuels change, and urban populations grow rapidly. These changes tend to bring about a shift in energy consumption from traditional or "noncommercial" fuels, such as wood and dung, to commercial fuels. In particular, they have resulted in rapid increases in petroleum consumption in many developing countries--complicating the problem of restraining petroleum consumption. It is difficult to separate the effects of structural changes in the economy from those of changing prices upon the composition of energy use.

This study will examine these and other factors affecting the composition of energy use in developing countries. We examine present energy use, and how it is likely to change in response to changes in energy prices, economic growth, and government energy policies. This analysis is of particular relevance to the need for substituting other energy sources for expensive, imported petroleum.

Trends in the Composition of Energy Use

By way of introduction, we may briefly review two major trends over the past three decades in the composition of energy use in developing countries.[1] The first trend has been a decline in the share of noncommercial or traditional fuels in total primary energy consumption, as mentioned above. Examples of this trend are provided in table 1-1.

The second trend has been the declining share of coal in total commercial energy use (coal, liquid fuels, gas, and primary electricity). As shown in table 1-2, in 1950, coal accounted for 39 percent of total energy consumption in developing countries, liquid fuels accounted for 55 percent, gas accounted for 4 percent, and primary electricity accounted for 2 percent. By 1973 the share of coal had fallen to 16 percent, while the shares of liquid fuels, gas, and primary electricity had risen to 67 percent, 13 percent and 4 percent, respectively. This substantial shift in the composition of energy use took place in the context of a rapid rise in total energy use. Thus LDC coal consumption in 1973 was double the 1950 level, despite the declining share of coal in the total. The increasing shares of the other fuels indicate particularly rapid rates of growth in total consumption, averaging 8 percent for oil, 13 percent for gas and 11 percent for primary electricity over this period.

Since 1973, the shares of these fuels in total commercial energy consumption have stabilized, bringing a halt to these apparently well entrenched patterns. Due to the still relatively short period of time since the major price increases, their most important effects may be yet to come.

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1. Unless otherwise stated, in presenting data we will use the term "developing countries" to refer to market or noncentrally planned developing countries as defined in United Nations Statistical Office, World Energy Supplies, Statistical Papers Series J (New York, UN), various issues. Note that these countries include the OPEC developing countries. Although OPEC countries account for a large share of energy production among developing countries, their share of energy consumption is much smaller. While we are primarily concerned with the energy problems of non-OPEC countries, it is much more difficult to obtain consistent data which excludes these countries.

Table 1-1. Share of Traditional Fuels in Total Primary Energy Consumption (percent)

Countries	1967	1970	1975
Brazil	43	36	27
Colombia	40	35	27
Egypt	2	3	2
India	28	27	25
Indonesia	71	64	58
Jamaica	9	7	4
Kenya	72	72	63
Korea	16	11	7
Mexico	8	6	4
Nigeria	88	86	70
Thailand	7	7	7

Source: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, volume II (Paris, OECD, 1979).

Table 1-2. Primary Commercial Energy Consumption in Developing Countries, Selected Years[a]

	Coal	Liquid fuels	Gas	Primary electricity	Total
Millions of metric tons of oil equivalent					
1950[b]	36	51	4	2	93
1973	73	310	62	17	462
1978	95	425	90	26	637
Percent of total					
1950	39	55	4	2	100
1973	16	67	13	4	100
1978	15	67	14	4	100
Annual growth rate (percent)					
1950-1973	3.2	8.1	12.7	10.6	7.2
1973-1978	5.4	6.5	7.9	9.5	6.6

Source: 1973 and 1978: United Nations Statistical Office, World Energy Supplies, 1973-1978, Statistical Paper Series J, no. 22, (New York, UN , 1979), p. 45; 1950: United Nations Statistical Office, World Energy Supplies, 1950-1974, Statistical Paper Series J, no. 19 (New York, UN , 1976), p. 11.

[a]Includes Developing Market Economics.

[b]For 1950, metric tons of coal equivalent figures were converted to metric tons of oil equivalent using 1.5 million metric tons of coal = 1 million metric tons of oil.

Differences Among Countries in the Composition of Energy Use

The countries which we term "developing" are extremely heterogeneous with respect to factors affecting energy use, such as economic structure, income levels, natural resource endowment, and transportation infrastructure. As shown for the eighteen countries in table 1-3, there is correspondingly wide variation in the composition of energy consumption.

For all of these countries except Pakistan and India, the share of oil in energy provided by fossil fuels in 1975 was over 50 percent. For twelve of these countries, the share of oil was over 70 percent, and for nine of these countries the share of oil was over 85 percent.

In contrast, there was wide variation among countries in the role of coal and natural gas. In seven countries the share of coal was less than 5 percent, while in six countries the share of coal exceeded 15 percent. In particular, the share of coal was very high in India (76 percent) and Korea (50 percent). Differences were even greater in the use of gas. In eleven countries, gas accounted for less than 2 percent of the energy supplied by fossil fuels, while in three countries (Bangladesh, Pakistan, and Mexico) its share exceeded 25 percent. There is also wide variation among countries in the consumption of hydroelectricity. Even with a generous allowance for the higher efficiency of hydropower, its share in commercial energy in 1975 was less than 10 percent in eight of the countries. However, in three countries this share exceeded 20 percent: Zaire (57 percent), Brazil (29 percent), and Colombia (20 percent).

How Different Fuels Are Used

Relatively little internationally comparable data are available which disaggregate energy consumption by fuel and end use. However, we may identify the most important end uses for the major fuels using data presented in appendix A. One consistent trend among countries is the large share of the transportation sector in the use of oil (table A-1). In six of the nine developing countries for which data were available on end uses of oil, the transportation sector accounted for over 40 percent of total oil use. In

Table 1-3a. Shares of Fossil Fuel Energy Consumption by Fuel in 18 Developing Countries (percent)[a]

Country	1967 Coal	1967 Oil	1967 Gas	1975 Coal	1975 Oil	1975 Gas
Bangladesh	--	--	--	16.1	54.1	29.8
Upper Volta	0.0	100.0	0.0	0.0	100.0	0.0
Zaire	37.3	62.7	0.0	15.3	84.7	0.0
India	82.2	17.4	0.4	76.0	23.0	1.0
Kenya	4.4	95.6	0.0	2.3	97.7	0.0
Indonesia	2.0	61.5	36.5	0.9	86.7	12.4
Pakistan	15.5	54.4	30.1	8.0	41.0	51.0
Thailand	2.1	97.9	0.0	1.6	98.4	0.0
Philippines	1.0	99.0	0.0	1.0	99.0	0.0
Egypt	5.9	93.2	0.9	11.6	78.5	10.0
Nigeria	14.6	72.8	12.6	4.2	85.4	10.5
Ecuador	0.0	100.0	0.0	0.0	99.1	0.9
Korea	70.6	29.4	0.0	49.9	50.1	0.0
Colombia	29.0	56.6	14.4	23.3	59.6	17.1
Turkey	39.5	60.5	0.0	27.0	73.0	0.0
Mexico	6.7	68.6	24.7	8.1	66.4	25.4
Portugal	25.0	75.0	0.0	7.5	92.4	0.1
Brazil	12.9	86.4	0.8	9.0	89.7	1.3

Table 1-3b. Relative Shares of Primary Electricity and Fossil Fuels in Commercial Energy Consumption in 18 Developing Countries (percent)[a]

Country	1967 Primary electricity[b]	1967 Fossil fuels	1975 Primary electricity[b]	1975 Fossil fuels
Bangladesh	--	--	8.1	91.9
Upper Volta	0.0	100.0	0.0	100.0
Zaire	48.2	51.8	56.9	43.1
India	7.6	92.4	9.7	90.3
Kenya	12.4	87.6	14.5	85.5
Indonesia	2.8	97.2	2.6	97.4
Pakistan	8.5	91.5	13.8	86.2
Thailand	8.3	91.7	10.3	89.7
Philippines	7.1	92.9	11.7	88.3
Egypt	8.0	92.0	14.4	85.6
Nigeria	2.6	97.4	14.4	85.6
Ecuador	8.8	91.2	7.7	92.3
Korea	2.0	98.0	1.7	98.3
Colombia	14.0	86.0	20.0	80.0
Turkey	6.2	93.8	7.9	92.1
Mexico	9.7	90.3	7.7	92.3
Portugal	31.1	68.9	22.3	77.7
Brazil	26.3	73.7	29.2	70.8

Sources: United Nations Statistical Office, World Energy Supplies 1972-1976, Statistical Papers, Series J, no. 21 (New York, UN, 1978) Table 2. United Nations Statistical Office, World Energy Supplies 1950-1974, Statistical Papers, Series J, no. 19 (New York, UN, 1976) table 2.

[a]Shares may not sum to 100 due to rounding.

[b]In order to roughly adjust for the difference in efficiency of use between primary electricity (hydro and nuclear generated electricity) and fossil fuels which are used to produce electricity, the heat content of hydro and nuclear electricity was multiplied by a factor of three.

general, industry, the household sector, and electricity generation, in that order, accounted for the next largest shares of oil use.[2,3]

The structure of coal and gas use in the developing countries is much more diverse than that of oil (tables A-2, A-3). In seven of the eleven countries for which data on end uses of coal are available, the industrial sector accounted for the largest share of coal use, while in two countries the household sector was most important. Electricity generation and transportation were each most important in one country.[4] In five of seven countries for which data on end uses of gas were available, industry accounted for the largest share of gas use, with the household sector the most important in the other two.[5] Electricity generation was another important use of gas.

Virtually all electricity is used in the industrial and household sectors. Most noncommercial fuels are used in the household sector, although industry uses significant quantities in some countries.

Outline of the Study

This study will examine in greater detail the patterns of energy consumption and supply described briefly above. In chapter 2 we investigate energy supply in the developing countries. Energy prices and resource endowments, through their effects upon supply, help to explain common trends in energy use in developing countries, as well as variation among countries. These same factors are likely to continue to affect supply conditions in the future.

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2. In this section we include Portugal and Turkey among developing countries.

3. These nine countries exclude Egypt, Indonesia and Korea, for which the unallocated share of oil consumption exceeds 36 percent.

4. These eleven countries exclude Colombia, for which the unallocated share of coal is 77 percent.

5. These seven countries exclude Indonesia and Colombia, for which the unallocated share of gas consumption exceeds 40 percent, and Kenya, Thailand and Korea, where gas consumption is insignificant.

In chapter 3 we consider factors affecting demand for energy in the developing countries. We first examine the changing composition of energy use in the major consuming sectors, and the reasons for these changes. Subsequently, we examine how overall structural changes in the economy affect the composition of energy use as the relative importance of different sectors changes.

In chapter 4 we discuss the effects of government policies on the composition of energy consumption and finally, in chapter 5, we summarize our conclusions and discuss their implications for the future. We also identify areas where further research is needed.

Data

A number of problems arise in collecting and analyzing data on energy use in developing countries. In comparing and aggregating energy use from different sources, it is necessary to assign energy weights to physical units of different energy sources. The most common practice is to weight different energy sources by their theoretical energy content. Consumption of fuels which are burned is generally presented in terms of the weight of a standard grade of oil or coal needed to produce an equivalent calorific value in combustion. However, it is difficult to calculate these conversion coefficients for the wide range of fuels used in developing countries--especially for noncommercial fuels.

For energy sources which produce electricity but do not involve combustion, such as hydroelectricity and nuclear power, one practice is to calculate the volume or weight of the standard grade of coal or oil needed to produce the same amount of electricity. Another is to report directly the calorific value of the electricity generated. The former practice, which is the one followed in this study, attributes an energy content to hydroelectricity and nuclear power roughly three times that of the calorific value of the electricity generated.

Where fuels are used for similar purposes with relatively similar efficiencies, aggregation of the total energy content of different fuels provides an indication of the "useful" energy contribution of different sources. However, the greater the variation in efficiency of energy use between different energy sources, the less meaningful aggregate measures or comparisons of total energy content will be. Total energy content may bear little relationship to the useful contribution of the energy source in production, or to the way in which different energy sources could be substituted for each other. As a result, aggregation and comparison of total energy contents of widely varying energy sources may be misleading.

An alternative to weighting fuels by total energy content is to weight fuels by "useful energy" provided. Since the efficiency of energy use varies widely between energy sources and uses, calculation of weights is difficult and somewhat arbitrary. However, in order to take account of this variation, we have presented some data in this study in terms of "useful" energy contribution as well as the more standard heat content measures. The "useful energy" data are calculated using the sector efficiency coefficients for each fuel presented in appendix B.

We have presented data for different groupings of developing countries depending on data availability. Supply data is given for eighteen developing countries representative of a wide range of per capita incomes, development paths, and resource endowments. Reflecting our focus in this study, these countries are primarily oil-importers. For purposes of comparison, data on four "developed" countries (Italy, Japan, Germany and the United States) are included in these tables.

Internationally comparable data for developing countries on end uses of energy are more limited. The International Energy Agency has published energy consumption balance sheets for the years 1967-77 for a number of developing countries.[6] However, in many countries a large share of energy use remains unallocated by sector. Thus in a number of cases our analysis was limited to eight countries--Brazil, India, Kenya, Mexico, Nigeria, Portugal, Thailand, and Turkey, as well as the four developed countries mentioned above. However, there is considerable diversity among these countries, and they include several of the largest developing countries.

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6. These are presented in International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979).

Chapter 2

SOURCES OF ENERGY IN DEVELOPING COUNTRIES

Introduction

Energy is either imported or produced domestically. We begin by examining the role of energy imports in the developing countries. More than half the oil consumed is imported; in contrast supplies of other fuels are mostly domestically produced. We examine the effects of declining world oil prices prior to 1970, followed by rising real oil prices on developing countries imports of oil.

Next we examine domestic energy production in developing countries. There is wide variation between countries in both present as well as potential production of domestic energy resources. Levels of import dependence, as well as the composition of energy use, may in large part be explained by differences in domestic energy resources. Finally, we review in greater detail factors affecting a number of different fuels in developing countries and consider their potential role in energy consumption.

Energy Imports and World Energy Prices

Table 2-1 shows the share of energy imports in energy consumption in developing countries for 1950, 1973, and 1978. In 1978, imports of energy petroleum products accounted for almost 60 percent of consumption, whereas imports of other fuels were very low relative to consumption. Put differently, consumption of coal, gas, and primary electricity is likely to be closely related to domestic production whereas consumption of oil is much less dependent upon domestic production. The share of imports in developing countries' oil consumption is high, even though the developing countries as a group are net exporters of oil, since the most important oil-exporting developing countries consume relatively little oil compared to their exports. However, the share of oil imports in developing countries' oil consumption has been declining since 1950 due to the expansion of both crude oil production and refinery capacity in developing countries.

Table 2-1. Commercial Energy Imports as Percentage of Consumption, Developing Market Economies, Selected Years

	Coal	Energy petroleum products[a]	Gas	Primary electricity
1950	14.1	86.9	12.8	0.4
1973	6.9	63.2	2.7	0.7
1978	10.4	59.0	2.5	0.7

Sources: United Nations Statistical Office, World Energy Supplies, 1950-1974, Statistical Papers, Series J, no. 19 (New York, UN, 1976), pp. 124, 263, 280, 568; United Nations Statistical Office, World Energy Supplies, 1973-1978, Statistical Papers Series J, no. 22, (New York, UN, 1979), pp. 104, 158, 238, 290.

[a]The figure for imports of energy petroleum products includes both direct imports as well as "indirect imports"--domestically refined energy petroleum products produced from imported crude oil. Indirect imports were estimated by multiplying the share of crude oil imports in apparent supply of crude oil by domestic production of energy petroleum products.

Imported oil alone accounted for 40 percent of developing countries total commercial energy consumption in 1978.[7] This is due in part to past trends in international oil prices. Between 1950 and 1970 the export price of Saudi Arabian oil fell from $6.60 to $3.48 per barrel in constant 1978 U.S. dollars.[8] While comparable data for steam coal are not available, steam coal prices in other markets stayed constant or did not decline as sharply, leading to an improvement in the competitive position of oil vis-a-vis coal. Responding to these price shifts, developing countries' imports of coal declined slightly between 1950 and 1973, while imports of oil more than quadrupled.

The decline in international oil prices also helps to explain the low level of exploration for and development of indigenous energy resources in developing countries during this period. For many countries imported oil was a cheaper energy source than was available domestically--especially given the high infrastructure costs associated with development of domestic resources.

In the 1970's, the trend towards cheaper oil was reversed. Between 1972 and 1979, the world export price of oil increased by a factor of 7.7 in current dollars, much greater than the rise in coal prices. These price changes have had two effects. First, they have increased the attractiveness of other fuels relative to oil. Secondly, the oil price rise has greatly increased the extent of domestic energy resources--both oil and nonoil--which may be economically developed. Although the real cost of energy has risen, the proportion of this cost which countries may potentially provide from their own resources has also risen.

Domestic Energy Supplies

While the evolution of world oil prices helps to explain common trends among developing countries in the composition of energy use, indigenous energy resource endowments help to explain many of the differences. Developing countries vary substantially in their endowments of energy resources. Table

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7. This figure may be derived by multiplying the share of oil in developing countries' commercial energy consumption--67 percent (see table 1-1)--by the share of imports in oil consumption--59 percent (see table 2-1).

8. World Bank, Commodity Trade and Price Trends, Report #EC-166/79 (Washington, D.C., World Bank, August 1979) pp. 92-95.

2-2 summarizes data presented in appendix C on the fossil fuel reserves and hydroelectric potential of developing countries. The grouping by row indicates countries' per capita endowments of fossil fuel reserves (oil, coal, and gas). For the purposes of this table, we categorize countries' endowments low if total reserves per capita are less than one ton of coal equivalent, medium if total reserves per capita are between one and ten tons of coal equivalent, and high if total reserves per capita exceed ten tons of coal equivalent. For reference, one ton of coal equivalent per capita is approximately the level of per capita commercial energy consumption in countries at a medium level of development, such as Korea (1.2 tce), Portugal (1.1 tce), and Mexico (1.3 tce).[9] It is roughly one third the level of per capita energy consumption of Italy and one tenth that of the United States. The groupings by column in table 2-2 indicate the level of hydroelectric potential. We categorize potential as low if annual energy per capita potentially available from hydroelectricity is less than .2 tons of coal equivalent, medium if potential is between .2 and 1 tce, and high if potential exceeds 1 tce. The table also indicates the degree of dependence upon imported oil in total energy consumption and whether or not countries are considered by the World Bank to have actual or potential fuelwood problems.

Although the data upon which table 2-2 is based are highly approximate, they do give some indication of the degree of diversity between countries in domestic energy reserves. As shown by the first row of table 2-2, a large number of developing countries do not presently have fossil fuel reserves equivalent to even one year's commercial energy consumption for a country at a "medium" level of development. Almost all of these countries are dependent upon oil imports for 75 percent of their commercial energy consumption. Furthermore, those countries with fuelwood problems are concentrated among this group. A smaller number of developing countries have intermediate or high per capita reserves of fossil fuels. These countries tend to be much less

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9. Figures for 1975 are from United Nations Statistical Office, World Energy Supplies, 1973-1978, Statistical Papers Series J, no. 22 (New York, UN, 1979) table 4. Metric tons were converted to tons by multiplying by 1.1023.

Table 2-2. Energy Reserves and Import Dependence[a] of Developing Countries[b]

Fossil Fuel Reserves[d]	Hydroelectric potential[c]: Low		Medium		High	
	Fuelwood problem	No fuelwood problem	Fuelwood problem	No fuelwood problem	Fuelwood problem	No fuelwood problem
Low	Burundi (3) Ghana (3) Malawi (3) Rwanda (3) Sri Lanka (4) El Salvador (4) Ethiopia (4) Haiti (4) Laos (4) Lesotho (4) Morocco (4) Philippines (4) Somalia (4) Togo (4) Yemen Arab Republic (4)	Lebanon (3) Dominican Republic (4) Guatemala (4) Ivory Coast (4) Jamaica (4) Jordan (4)	Zambia (2) Afghanistan (3) Chad (4) Benin (4) Guinea (4) Honduras (4) Kenya (4) Mali (4) Mauritania (4) Senegal (4) Sierra Leone (4) Sudan (4) Tanzania (4) Uganda (4)	Nicaragua (4) Panama (4) Portugal (4) Uruguay (4)	Burma (0) Central African Republic (4) Liberia (4) Madagascar (4) Nepal (4) Niger (4) Upper Volta (4)	Costa Rica (4) Papua New Guinea (4) Paraguay (4)
Medium	Pakistan (2) Thailand (4)				Zaire (0) Cameroon (4)	
High	Indonesia (0) Nigeria (0) Egypt (0) India (1) Bangladesh (2)	Mexico (0) Algeria (0) Malaysia (0) Syria (0) Trinidad and Tobago (0) Tunisia (0) Korea (1) Turkey (3)		Peru (0) Argentina (1) Chile (2) Brazil (3) Yugoslavia (2)	Congo (0) Ecuador (0)	Boliva (0) Colombia (1)

Sources: World Bank, Energy in Developing Countries (Washington, D.C., World Bank, August 1980), pp. 80-86; World Bank, World Development Report, 1980 (Washington, D.C., World Bank, August 1980), pp. 110-111.

[a]The figures in parentheses indicate net oil imports as a percentage of commercial fuel demand, as follows: (0:) net oil exporters; (1:) 26-50%; (3:) 51-75%; (4:) 76-100%.

[b]Does not include centrally planned economies, capital surplus oil exporters, or countries with populations less than one million. Within each section, countries in the left-hand column are those considered by the World Bank to have actual or potential fuelwood problems.

[c]Categories are defined as follows: Low: Annual energy potential per capita under conditions of average flow from installed and installable capacity utilized twelve hours per day less than .2 tons of coal equivalent; Medium: annual energy potential per capita between .2 and 1 tce; High: annual energy potential per capita more than 1 tce. Conversion assumes tce per year = 536.1 x potential capacity in megawatts (based on assumption of 1 mwh = .122 tce).

[d]Categories are defined as follows: Low: Less than 1 ton of coal equivalent per capita; Medium: between 1 and 10 tce per capita; High: more than 10 tce per capita.

dependent upon imported foreign oil. This group includes the larger and more populous developing countries. It is primarily in these countries that energy sources other than oil play a significant role in consumption.

Perhaps the most striking feature of table 2-2 is that most of those countries which are most dependent upon imported oil do not ... present have fossil fuel reserves which would allow them to substantially reduce this dependence. In many of these countries relatively little exploration has taken place to date. Further exploration may result in the discovery of large new reserves in some countries, and in some countries hydroelectric potential could be substantially further developed. Nuclear power and unconventional energy sources such as solar power and biomass may also eventually become important domestic sources of energy. However, rapid changes in the structure of energy use are unlikely. Facilities to produce and deliver oil, coal, natural gas, and hydro and nuclear power are highly capital intensive and require long lead times to plan and construct. Thus, in the near future most energy importers are likely to remain dependent upon energy imports. Usually this will mean imported oil, as coal, natural gas, and electricity are difficult to import and transport costs are high--especially for countries whose internal transport system are under-developed. In those countries with moderate to high existing reserves of fossil fuels, the range of energy options is great. However, the time required to develop these options--as well as demand limitations--will limit the pace at which adjustments may occur.

The availability of financing and technical and managerial skills--often provided by foreign assistance and investment--have also influenced the development of domestic energy supplies. Countries such as Egypt, Ghana, and Pakistan have constructed large hydroelectric generating facilities with the help of foreign aid. Until recently, due to excess supply in world markets, relatively less attention was devoted to exploration for and development of fossil fuels. Only a few countries developed production and transportation facilities for coal and natural gas. These tended to be larger countries with substantial industrialized or modern enclaves, where domestic demand could support production, and indigenous financing and expertise were available. Examples are India, Korea, and Turkey where coal is produced, and Mexico and Pakistan, where gas resources have been developed.

The plight of developing countries facing high energy import bills has increased the attention focused by international aid institutions upon providing assistance to developing countries for exploration and development of new energy resources. For example, in August 1980 the World Bank proposed the establishment of a new facility devoted entirely to financing energy investments. Increased demand and higher prices for fossil fuels, as well as uncertainty about the availability of traditional supplies, has also led to an increase in private foreign investment for exploration and development of LDC energy resources.

The following sections will review, in greater detail, factors affecting the availability in developing countries of oil, natural gas, coal, hydro and nuclear power, noncommercial fuels, and nonconventional energy sources.

Petroleum and Natural Gas

Since they are often found together, we will discuss the supply of petroleum and natural gas in the same section. Petroleum is the most important commercial fuel in most developing countries, providing almost all commercial energy used in the transportation sector, as well as a major share of energy used in the industrial, household, and electricity generation sectors of most countries. Petroleum accounted for 67 percent of commercial energy use in developing countries in 1978. Natural gas, used in the industrial, household, and electricity generation sectors and as a raw material for the fertilizer and other chemical industries, accounted for 14 percent of commercial energy use.[10] Transportation of natural gas was limited to land pipelines until techniques were developed in the 1960s for ocean transport of liquified natural gas.[11] This tended to limit gas consumption to those countries which were producers. Thus, in 1978 only 2.5 percent of developing countries' gas consumption consisted of imports, compared with 59 percent of oil consumption (table 2-1). Only three developing countries--Argentina, Mexico, and Malaysia--imported

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10. UN Statistical Office, World Energy Supplies, 1973-1978, p. 7.

11. World Bank, Energy in the Developing Countries (Washington, D.C., World Bank, August 1980), p. 26.

natural gas.[12] Development of gas supplies for domestic use has also been limited by the high cost of pipelines and distribution facilities, which require large and concentrated markets to be competitive with oil products. As a result, if local markets did not exist, associated gas (gas found inassociation with oil) was usually flared, and discoveries of nonassociated gas have not been developed.[13] In addition, large fixed investments and susceptibility of the gas industry to government regulation have lowered the attractiveness of gas development to foreign investors.[14]

Prior to 1970 low-cost Middle East discoveries helped to keep oil prices low and to divert resources from exploration and investment in higher cost areas. According to the World Bank, "before the price increases of the mid-seventies all but a few of the non-OPEC developing countries would have been ill-advised" to spend money developing petroleum reserves. "Imported oil was cheap, and expenditures on developing local supplies would have been a particularly uneconomic form of import substitution."[15] Since the oil price increases, however, the prices of oil and gas are high enough to develop known reserves which would previously have been uneconomic due to small size or high transport costs, as well as to undertake exploration in new areas where supply development would previously have been uneconomical.

Table 2-3 presents a breakdown of noncapital surplus developing countries by status of oil and gas production, reserves, and prospects for oil or gas discoveries. In 1978, oil or gas was produced in twenty-seven of these countries, of which sixteen were net oil exporters and eleven were net importers of oil. Another nine countries had proven reserves of oil or gas, while exploration was taking place with favorable geological prospects in thirty-one countries. Tables 2-4 and 2-5 present data on oil and gas

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12. UN Statistical Office, World Energy Supplies, 1973-1978, pp. 228-233.

13. World Bank, Energy in the Developing Countries, p. 26.

14. World Bank, A Program to Accelerate Petroleum Production in the Developing Countries (Washington, D.C., World Bank, January 1979) p. 7.

15. World Bank, A Program to Accelerate Petroleum Production, p. 14.

Table 2-3. Noncapital Surplus Developing Countries: By Level of Oil and Gas Production, Reserves and Exploration[a]

Oil exporters[c]	Oil importing countries producing either oil or gas	Oil importing countries which do not produce oil or gas but have proven resources	Oil importing countries in which exploration is taking place with favorable geological prospects for oil or gas discoveries	Oil importing countries with unfavorable prospects for oil or gas discoveries
Trinidad and Tobago (O,G)	Argentina (O,G)	Philippines (O,G)	Sri Lanka	Nepal
Algeria (O,G)	Chile (O,G)	Thailand (O,G)	Korea	Singapore
Mexico (O,G)	Colombia (O,G)	Cameroon (G)	Vietnam	Hong Kong
Congo (O,G)	Brazil (O,G)	Chad (O)	Jordan	Western Samoa
Syria (O,G)	Turkey (O)	Ivory Coast (G)	Yemen Arab Republic	Zambia
Nigeria (O,G)	Guatemala (O)	Tanzania (G)	Yemen PDR	Mauritius
Malaysia (O,G)	India (O,G)	Burundi	Mozambique	Botswana
Ecuador (O,G)	Pakistan (O,G)	Papua New Guinea	Ethiopia	Kenya
Tunisia (O,G)	Ghana (O,G)	Rwanda	Madagascar	Lesotho
Egypt (O,G)	Morocco (G)		Somalia	Malawi
Indonesia (O,G)	Bangladesh (G)		Togo	Uganda
Peru (O,G)			Senegal	Gabon
Bolivia (O,G)			Benin	Niger
Zaire (O,G)			Central African Republic	Upper Volta
Burma (O,G)			Gambia	
Oman (O,G)			Guinea	
			Mali	
			Niger	
			Sierra Leone	
			Surinam	
			Uruguay	
			Jamaica	
			Guyana	
			Paraguay	
			Dominican Republic	
			Nicaragua	
			Costa Rica	
			Panama	
			El Salvador	
			Honduras	
			Haiti	

Sources: World Bank, Energy in Developing Countries (Washington, D.C., World Bank, August 1980) pp. 80-81; R. Vedavelli, Petroleum and Gas in Non-OPEC Developing Countries; 1976-1985, World Bank Staff Working Paper No. 289 (Washington, D.C., World Bank, April 1978) Annex II; United Nations Statistical Office, World Energy Supplies, 1972-1976. Statistical Papers Series J, no. 21 (New York, UN, 1978).

[a]Does not include capital-surplus developing countries, centrally planned economies, or countries with population less than one million.

[b]The symbols O and G indicate that the country has proven reserves of oil or gas, respectively.

[c]Classification as importers or exporters based upon 1978 U.N. trade figures.

Table 2-4. Oil Production and Reserves of Noncapital Surplus Developing Countries

Oil exporters	Reserves per capita 1978 (mtoe)	Production per capita 1978 (mtoe)	Ratio of reserves to production 1978	Production 1967 (mtoe)	Production 1973 (mtoe)	Production 1978 (mtoe)	Projected production 1985 (mtoe)	Rates of growth (percent) 1967-73	1973-78	1978-85
Trinidad/Tobago	82.7	10.91	7.6	9.2	8.8	12.0	8.6	-0.74	6.40	-4.64
Algeria	62.3	3.07	20.3	38.4	49.6	54.0		4.36	1.71	
Mexico	62.1	0.86	72.2	18.7	23.3	56.5	110.5	3.73	19.38	10.77
Congo	34.7	1.07	31.5	0.05	2.1	1.6	0.8	86.44	-5.29	-9.43
Syria	32.1	1.23	26.1	---	5.5	10.0	10.4	---	12.70	.56
Nigeria	28.1	1.10	25.5	16.8	101.8	89.0		35.02	-2.65	
Malaysia	27.4	0.73	37.5	0.05	4.4	9.7	13.0	110.90	17.13	4.27
Ecuador	18.3	1.26	14.5	0.3	10.6	9.8		81.15	-1.56	
Tunisia	11.2	0.72	15.6	2.2	3.9	4.3	7.2	10.01	1.97	7.64
Egypt	10.1	0.53	19.1	5.6	8.5	21.0	58.5	7.20	19.83	15.76
Indonesia	9.2	0.66	13.9	25.3	66.2	90.0		17.39	6.34	
Peru	5.1	0.42	12.1	3.5	3.5	7.0	9.1	0.0	14.87	3.82
Bolivia	3.7	0.34	10.9	1.9	2.2	1.8	5.2	2.47	-3.93	16.36
Zaire	0.7	0.04	17.5	---	---	1.1	4.6	---	---	22.68
Burma	0.1	0.05	2.0	0.6	1.0	1.5		8.89	8.45	
Oman				2.9	14.6	15.7	17.6	30.92	1.46	1.65
Total				125.5	306.0	385.0		16.01	4.70	
Oil importers										
Argentina	11.8	0.86	13.7	16.0	21.5	22.7	26.0	5.05	1.09	1.96
Chile	4.9	0.07	70.0	1.6	1.5	0.8	2.0	-1.07	-11.81	13.99
Colombia	3.6	0.27	13.3	9.6	9.5	6.8	6.5	-0.17	-6.47	-.64
Brazil	1.3	0.07	18.6	7.1	8.1	8.1	35.8	2.22	0.0	23.65
Turkey	0.4	0.06	6.7	2.8	3.6	2.5	2.6	4.28	7.03	.56
Guatemala	0.3	0.01	6.0	n.a.	n.a.	0.03	1.2			69.38
India	0.3	0.02	15.0	5.7	7.2	11.2	23.4	3.97	9.24	11.10
Pakistan	0.3	0.01	30.0	0.5	0.4	0.5	2.1	-3.65	4.56	22.75
Ghana	0.08	0.02	(.4)	---	---	0.2		---	---	
Philippines	0.07	---		---	---	---	2.1	---	---	
Bangladesh	0.04	---		---	---	---	0.8	---	---	
Total				43.3	51.8	52.8		3.03	.38	

Sources: Reserves: World Bank, Energy in Developing Countries (Washington, D.C., World Bank, 1980) pp. 80-81; Population: World Bank, World Development Report, 1980 (Washington, D.C., World Bank, August 1980) pp. 110-111; Production 1967 and 1973: United Nations, World Energy Supplies, 1950-74, Statistical Papers Series J, no. 19 (New York, UN, 1976) p. 194; Production and Imports 1978: United Nations, World Energy Supplies 1973-78, Statistical Papers Series J, no. 22 (New York, UN, 1979) pp. 126-135; Projected Production 1985: R. Vedavelli, Petroleum and Gas in Non-OPEC Developing Countries: 1976-1985, World Bank Staff Working Paper No. 289 (Washington, D.C., World Bank, April 1978) p. 5.

[a]Excludes centrally planned economies. Barrels of oil equivalent were converted to metric tons of oil equivalent using 1 boe = .13 mtoe.

Table 2-5. Natural Gas Production and Reserves in Noncapital Surplus Developing Countries, 1975[a]

Country	Per capita production (thousand kilocalories)	Per capita reserves (thousand kilocalories)	Production (thousand teracalories)	Reserves (thousand teracalories)	Ratio of reserves to production	Gas imports (thousand teracalories)	Gas exports (thousand teracalories)
Trinidad/Tobago	13016.6	1,941,800	14.1	2101	149	---	---
Algeria	3568.6	2,140,700	56.2	33710	600	---	39.9
Bolivia	2545.3	270,700	14.1	1525	108	---	12.9
Argentina	2498.2	156,900	63.4	3982	63	12.9	---
Mexico	2060.0	323,900	123.5	19409	157	2.3	---
Afghanistan	2016.4	---	27.6	---	---	---	26.6
Chile	1068.0	121,500	11.0	1245	113	---	---
Colombia	741.6	56,400	17.5	1330	76	---	---
Pakistan	644.2	54,700	44.6	3784	85	---	---
Tunisia	421.5	68,200	2.4	381	159	---	---
Egypt	279.3	35,700	10.4	1330	128	---	---
Peru	260.0	29,200	4.0	449	112	---	---
Indonesia	162.7	41,200	21.4	5447	255	---	---
Congo	118.9	459,000	0.2	610	3050	---	---
Bangladesh	56.2	30,200	4.4	2372	539	---	---
Brazil	55.0	5,700	5.9	610	103	---	---
Nigeria	49.9	131,700	3.7	9884	2671	---	---
Morocco	42.4	---	0.71	---	---	---	---
Ecuador	27.2	52,100	0.2	369	1845	---	---
India	14.0	3,000	8.5	2033	239	---	---
Rwanda	2.2	---	0.009	---	---	---	---
Burma	1.6	900	.05	28	560	---	---
Thailand	---	---	---	1920	---	---	---
Syria	---	---	---	353	---	---	---
Malaysia	---	---	0.7	5930	8471	1.4	---
Ghana	---	---	---	14	---	---	---
Zaire	---	---	---	449	---	---	---
Cameroon	---	---	---	288	---	---	---

Sources: Gas Production, Imports and Exports: United Nations, World Energy Supplies, 1972-76, Statistical Papers Series J, no. 21 (New York, UN, 1978) pp. 147-152: Reserves: World Bank, Energy in Developing Countries (Washington, D.C., World Bank, August 1980) pp. 80-81, Population: World Bank, World Bank Atlas (Washington, D.C., World Bank, 1977) p. 8.

[a] Excludes centrally planned economies.

[b] Reserves were converted from million barrels of oil equivalent to thousand teracalories by multiplying by a conversion factor of 1.412.

production and reserves. The sixteen net oil-exporting countries produced 385 million tons of oil in 1978, or 12.9 percent of world production. The nine oil-importing oil-producers produced 53 million tons, or 1.8 percent of world production. Of these nine countries, all except Colombia and Argentina are more than 50 percent dependent upon imports for consumption.[16] Production of natural gas in the noncapital surplus developing countries in 1975 totaled 435 thousand teracalories, or only 3.9 percent of world production. The ratios of proven reserves to production were much higher than for oil, indicating that production could be expanded considerably from known reserves.

What are the prospects for discovery and development of additional oil and gas resources in the developing countries? Approximately 600 sedimentary basins have been identified throughout the world with potential for oil or gas discoveries. About 400 of these have had some drilling to date. The 200 basins which have not been explored are mostly located in areas where development of oil and gas resources would be high-cost, such as the Arctic and deep offshore areas, and continental interiors such as the mid-upper Amazon and central Africa.[17] Many of the basins which remain to be explored are in LDCs. A study conducted for the World Bank of oil and gas prospects in seventy LDCs concluded that of the ten nonoil producers with known reserves, six had "very high" or "high" potential reserves (over 750 million barrels) and four had "fair" or "low" potential reserves (less than 750 million barrels). Of the forty-five nonoil producers without discoveries to date, five had "very high" or "high" potential reserves, and forty had "fair" or "low" potential reserves. However, even a "low" level of reserves may be very significant for a small country which consumes relatively little oil.[18]

Despite the favorable prospects for oil and gas exploration in a number of countries, the oil industry has tended to concentrate its increased drilling in

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16. This statement refers to 1978. Data are from UN Statistical Office, World Energy Supplies, 1973-1978, pp. 126-135.

17. World Bank, A Program to Accelerate Petroleum Production, p. 15.

18. World Bank, A Program to Accelerate Petroleum Production, p. 17.

sedimentary basins in which production has already been developed, where infrastructure has already been developed and which are closer to markets. Although exploratory wells were drilled in seventy-one non-OPEC LDCs between 1969 and 1979, and another nineteen were explored by seismic surveys, the drilling density was far lower in these countries than in the OPEC or the developed countries. Exploratory drilling in the non-OPEC LDCs actually declined between 1972-73 and 1975-76. Over this period, expenditures on geophysical work declined in Asia by 31 percent and in Africa by 12 percent, and increased in Latin America by only 4 percent, compared with a 60 percent increase in the United States.[19] Of the twenty-three countries considered to have "high" or "very high" prospects for oil and gas reserves by the World Bank study mentioned above, only seven were considered to have been explored adequately. Countries where the World Bank study suggested increased exploration included India, Argentina, Turkey, Philippines, Colombia, Peru, Pakistan, and Vietnam.[20]

In addition to high costs, other factors have also slowed the pace of oil and gas exploration in the oil-importing developing countries. Most LDCs face a shortage of risk capital for oil exploration and need the capital as well as the expertise of foreign oil companies. However, LDC governments and state oil companies often lack technical and negotiating expertise for dealing with foreign oil companies. They often do not have accurate geological information which would help them and foreign investors in assessing the potential for discoveries and the adequacy and fairness of financial rewards to companies. A study done for the World Bank concluded that in about fifty of seventy developing countries, "the government or the state oil company urgently needs help in a variety of training and institution building activities."[21]

Recent World Bank projections may give some indication of the potential for increases in oil and gas production in the oil-importing developing countries. The projections suggest that oil production will increase in the

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19. World Bank, A Program to Accelerate Petroleum Production, pp. 17-18.

20. World Bank, A Program to Accelerate Petroleum Production, p. 18.

21. World Bank, A Program to Accelerate Petroleum Production, pp. 10, 16.

oil-importing developing countries at a rate of 8.9 percent between 1975 and 1985, compared with a rate of 5.2 percent for consumption. As a result, domestic production as a share of consumption in these countries is projected to rise from 28 percent to 40 percent. Gas production (for all non-OPEC developing countries, including oil exporters) is projected to rise at a rate of 12 percent, compared with an 11 percent rate of increase in consumption. Thus, substantial increases in the production of both oil and natural gas are possible in a number of countries, and may help to significantly reduce the burden of oil imports for these countries.[22]

Coal

Potential resources of coal are very large. World coal reserves which are exploitable at current prices and technologies are nearly five times as great as oil reserves. Geological resources are many times this amount. While only a small fraction of world coal reserves are located in developing countries, these reserves are still very large. For developing countries endowed with coal, increased use of coal may provide an important alternative to imported petroleum. For developing countries without coal reserves, coal imports may in some cases provide a cheaper and more secure source of imported energy.[23]

As shown in table 2-6, between 1950 and 1974 the share of coal in total commercial primary energy consumption declined dramatically in the developing countries as well as the developed countries. By 1974, the share of coal in developing countries' primary energy consumption had fallen below 12 percent in every region except the Far East. The continued importance of coal in the Far East was primarily due to India, where coal accounted for 72 percent of primary energy consumption. Use of coal on a large scale was limited to a relatively few developing countries. Among the nonCommunist LDCs, India alone accounted for over 60 percent of coal consumption. Five countries--India, Korea, Turkey, Mexico and Brazil--accounted for over 84 percent of LDC coal consumption.[24]

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22. World Bank, A Program to Accelerate Petroleum Production, p. 3.

23. World Bank, Energy in the Developing Countries, p. 32.

24. UN Statistical Office, World Energy Supplies, 1950-1974, Statistical Papers Series J, no. 19 (New York, UN, 1976) table 2.

Table 2-6. Share of Coal in Total Primary Energy Consumption (percent)

	1950	1974
Developed market economies	56.9	22.6
Developing market economies	38.7	18.4
Centrally planned economies	85.5	53.9
African developing countries[a]	33.1	11.6
South American developing countries[a]	20.9	5.1
Central American developing countries[a]	6.4	5.4
Middle Eastern developing countries[a]	40.1	7.0
Far Eastern developing countries[a]	71.3	41.7

Source: United Nations Statistical Office, World Energy Supplies: 1950-1974, Statistical Papers, Series J, no. 19 (New York, UN, 1976) Table 2.

[a]Excludes centrally planned economies.

The declining role of coal over the period 1950-74 may be explained by the availability of cheaper, cleaner, and easier-to-use petroleum. With the alternative of oil, there was little incentive for countries to develop indigenous coal reserves, or in some cases even to maintain existing production. With the rapid increase in oil prices after 1973, domestically produced coal has become more attractive as an alternative to imported oil. In addition, the relative attractiveness of imported coal has increased.

Despite these changes, several factors are likely to retard substitution of coal for petroleum, particularly in the short run. First, exploration for coal has been limited. Known reserves are concentrated in relatively few countries, and many LDCs have only small known reserves, or none at all. Secondly, infrastructure costs for mining, transportation and handling of coal are very high and are likely to hinder expansion of coal use in countries where extensive transportation facilities do not already exist. Third, international markets for coal are relatively underdeveloped, although they are likely to expand in the future. Together, these factors have resulted in high supply costs for coal relative to other fuels in the majority of LDCs without significant coal reserves, and in countries where extensive transportation infrastructures do not exist. In the long run, coal supply constraints may be significantly reduced through coal exploration, further development of indigenous coal reserves, construction of transportation and handling facilities, and expansion of coal imports.

Developing countries account for about 2 percent of world geological coal resources and 10 percent of recoverable coal reserves, or 230 billion tce of geological resources and 65 billion tce of recoverable reserves.[25] At current rates of consumption LDC recoverable reserves of coal could provide for total

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25. Resources and reserves figures are from the World Bank, Coal Development Potential and Prospects in the Developing Countries (Washington, D.C., World Bank, October 1979) Annex II, p. 1. "Geological resources are defined as coal occurences which may acquire some economic value for mankind in the future," while coal reserves are "coal occurences which are exploitable subject to current economic and technical conditions" (Annex I, p. 1).

LDC commercial energy consumption for sixty-nine years.[26] However, LDC coal resources and reserves are highly concentrated. Five countries--India, Swaziland, Botswana, Indonesia, and Brazil--account for 77 percent of LDC geological coal resources and 62 percent of recoverable reserves. India alone accounts for 52 percent of presently technically and economically recoverable coal reserves. Recoverable resources per capita exceed ten tons in only thirteen countries. Botswana, Zimbabwe, Brazil, India, Venezuela, and Turkey have the highest per capita recoverable reserves of coal.[27]

There has been relatively little exploration for coal in developing countries, so it is possible that considerably more extensive coal reserves will be discovered. Prior to the oil price rise of 1973, there was little interest in coal exploration among developing country governments, which concentrated on exploring for more valuable resources such as copper and iron ore, or among international mining companies, due to flagging demand and the existence of abundant coal resources in the developed countries. Recently, developing countries have reclassified much of their coal resource base, but relatively little new coal exploration has begun.

Coal production has lagged along with exploration. Of the thirty-six nonCommunist developing countries for which data on coal resources were presented in a recent World Bank study, coal was mined in only twenty-five countries in 1975, and per capita production exceeded 20 kilograms in only twelve countries. Only in Korea, with the highest per capita coal production of any developing country, does the rate of exploitation of reserves exceed 1 percent per year.[28] One reason for the slow development of coal resources is

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26. In 1978, commercial energy consumption in developing countries was 936 million metric tce (UN Statistical Office, World Energy Supplies, 1973-1978, p. 15).

27. World Bank, Coal Development Potential and Prospects, p. 3, Annex 2, p. 1 for coal reserve figures; World Bank, World Bank Atlas, 1977 (Washington, D.C., World Bank, 1977) for population figures.

28. See UN Statistical Office, World Energy Supplies, 1972-1976, Statistical Papers Series J, no. 21 (New York, UN, 1978) table 3 for coal production figures; see World Bank, World Bank Atlas, 1977 for population figures; World Bank, Coal Development Potential and Prospects, Annex II, p. 1 for coal reserves figures.

high infrastructure costs for mining and transportation of coal. The World Bank estimates that $US 20 billion would be necessary to achieve an increase in LDC coal production from 176 million tons in 1977 to 440 million tons in 1990--an optimistic estimate of potential LDC output.[29]

In particular, the marginal cost of coal production in developing countries is much higher than in developed countries, due to the lack of shipping and rail facilities. According to the World Bank, transport costs are likely to average 40-60 percent of delivered coal costs in the LDCs during the 1980s, compared with 10-30 percent in the developed countries.[30] Although the construction of transport infrastructure is likely to bring numerous other benefits to developing countries, it greatly increases the lead time necessary for development of coal resources.

International trade in coal is relatively underdeveloped, compared with petroleum. Only 8.4 percent of world coal production was exported in 1975, compared with 53.5 percent of petroleum. Thermal coal accounted for less than 25 percent of world coal trade. Among developing countries in 1975, only Brazil, Egypt, and Argentina imported more than one million tons of coal. Market LDCs as a group imported 9.9 million tons of coal, or 6.6 percent of consumption. Over twenty-five noncoal-producing countries imported some coal in 1975, although generally in small quantities: only Egypt, Bangladesh and Peru imported more than 200 thousand tons.[31] For some developing countries, imported coal represents a cheaper and more secure alternative for meeting energy requirements than does imported petroleum. Taiwan and Korea have announced plans to develop power plants using imported coal from South Africa and Australia. However, large-scale use of coal imports requires extensive transportation and handling facilities which limits this option for many countries.[32]

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29. World Bank, Coal Development Potential and Prospects, p. 17.

30. World Bank, Coal Development Potential and Prospects, p. 19.

31. UN Statistical Office, World Energy Supplies, 1972-1976, table 3.

32. UN Statistical Office, World Energy Supplies, 1972-1976, table 3, table 4, and table 6.

Hydroelectric Power

An important trend in the composition of energy use in developing countries has been the increasing share of electricity in final energy consumption. Between 1950 and 1973 developing countries' production of electricity grew at an average annual rate of 10.5 percent, compared to a growth rate of 7.4 percent for total commercial energy consumption. Between 1973 and 1978 these rates fell to 8.3 percent and 6.6 percent, respectively.[33]

Hydroelectric power is an important source of electricity generation in the developing countries, providing over 43 percent of electricity generation in 1975, compared with only 23 percent in the developed countries.[34] As shown in table 2-7, the share of hydropower was much higher for countries such as Zaire (97.5 percent), Brazil (92.2 percent), and Nigeria (72.9 percent).

In the short run, the maximum supply of hydroelectric power is fixed. Total generation of hydroelectricity can in general only be increased through construction of new dams and powerhouses which require years of planning and construction. In the long run, however, there is considerable potential for expansion of the supply of hydroelectricity in many developing countries. This potential depends upon a variety of factors. These include the terrain and rainfall of the country, which determine the theoretical potential for hydroelectricity generation, as well as the costs of constructing and operating hydroelectric facilities. All else being equal, the higher the price of electricity, the more projects will be economic and hence the greater the long-run supply potential for hydroelectricty.

Because of the variety of factors involved, it is difficult to estimate economic supply potential for hydroelectricity. Some indication may be gained from the calculation of theoretical potential. But the percentage of theoretical potential which could be economically developed will vary widely from country to country. The world energy conference has published data on

33. UN Statistical Office, World Energy Supplies, 1950-1974, pp. 11, 707; UN Statistical Office, World Energy Supplies, 1973-1978, pp. 15, 275.

34. UN Statistical Office, World Energy Supplies, 1972-1976, p. 189.

Table 2-7. Production of Electricity, Share of Production by Type, and Utilization of Hydroelectric Capacity, Selected Developing Countries, 1975

Country	Total (billion kilowatt hrs)	Thermal (percent)	Hydro (percent)	Nuclear (percent)	Installable hydroelectric Capacity (billion kilowatt hours)	Hydroelectricity production, 1975, as share of installable capacity (percent)
Bangladesh	1.7	70.6	29.4	0	7	7.7
Upper Volta	0.1	100.0	0.0	0	48	0.0
Zaire	3.8	2.5	97.5	0	660	0.6
Pakistan	10.1	46.4	48.2	5.5	105	4.6
India	85.9	58.2	38.8	3.1	280	11.9
Kenya	1.0	33.2	66.8	0	54	1.2
Egypt	10.4	34.5	65.5	0	15	45.3
Indonesia	4.0	55.1	44.9	0	150	1.2
Nigeria	3.2	27.1	72.9	0	8	28.3
Thailand	8.9	61.7	38.3	0	23	15.1
Philippines	13.7	67.0	33.0	0	20	23.0
Korea	20.8	91.9	8.1	0	10	17.0
Ecuador	1.7	60.8	39.2	0	126	0.5
Colombia	14.5	31.5	68.5	0	300	3.3
Mexico	43.3	63.9	36.1	0	99	15.7
Turkey	15.6	62.2	37.8	0	65	9.0
Brazil	78.1	7.8	92.2	0	519	13.9
Portugal	10.7	40.0	60.0	0	18	36.2
Italy	147.3	66.8	30.6	2.6	51	89.0
Japan	475.8	76.6	18.1	5.3	130	66.4
USA	2300.0	76.1	15.3	8.6	702	43.7
Germany	301.8	87.2	5.7	7.1	22	78.3

Source: United Nations Statistical Office, World Energy Supplies, 1972-1976, Statistical Papers, Series J, no. 21, (New York, UN, 1978) pp. 189-201; World Energy Conference, Survey of Energy Resources, 1974 (New York, United Nations Council of the World Energy Conference, 1974) pp. 187-189.

installed and installable capacity, defined as capacity which has been or could be installed to utilize hydroelectric potential, without reference to the economic costs of such projects. These data are presented on a per capita basis in appendix C.

There is considerable variation in installable capacity between countries. Expressed in tons of coal equivalent of electricity per capita which could be generated in one half-year under conditions of average flow, installable capacity per capita ranges from as high as 4.13 in Madagascar to near zero in Tunisia (see appendix C). Countries also vary widely in their utiliziation of installable capacity. In general, hydroelectric generation represents a much smaller proportion of installable capacity in developing countries than in the developed countries. Hydroelectricity generation as a share of installed capacity is less than 2 percent in Upper Volta, Ecuador, Zaire, Kenya, and Indonesia (table 2-7). In contrast, hydrogeneration exceeds 60 percent in Japan, Italy and Germany. Those differences in capacity utilization can be explained partly by differences in the location of hydroelectric potential. As an example, we may contrast Egypt and Ecuador. Hydroelectricity generation in Egypt is nearly ten times that of Ecuador, although installable capacity in Ecuador is more than eight times that of Egypt. In Egypt, hydroelectric facilities are dominated by the Aswan Dam alone, and transported to closely concentrated users along the Nile River.[35] In contrast, hydroelectric capacity in Ecuador is located on numerous small rivers in remote mountain areas.

Hydroelectricity represents an important potential source of energy. However, hydroelectric power can supply only a relatively small share of the total future energy needs of most countries. As shown in appendix C, for approximately one-third of all developing countries, theoretical potential could supply less than .2 tons of coal equivalent per capita annually--or less than one-fifth the energy consumption of a country at a medium level of development.

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35. World Energy Conference, Survey of Energy Resources 1974 (New York, United States National Committee of the World Energy Conference, 1974), pp. 154, 187. Installable capacity is for average flow conditions.

Nuclear Energy

In 1978, nuclear energy supplied just over 1 percent of electricity generated in the developing countries, compared with 7 percent for the world as a whole. Only four developing countries--Korea, Pakistan, Argentina, and India--had installed nuclear units which provided 9 percent, 5.4 percent, 5.3 percent and 3.3 percent, respectively, of total electricity production.[36] The relatively minor role played by nuclear energy in the past in developing countries may be explained by a number of factors. First, the smaller the reactor, the higher the cost per unit of capacity for reactors. As a result, relatively large reactor sizes--presently about 600 mW--are necessary for economical operation. While commercial reactors with capacity as low as 200 mW have been constructed, manufacturers have tended to emphasize much larger designs. The need for a large grid for economical operation of reactors has limited their competitiveness in developing countries, where demand for electricity tends to be less concentrated. High capital costs, including a large foreign exchange component, have also slowed the development of nuclear power. Most financing for present and planned installations has been provided by supplier credits and bilateral agencies.[37] As a result of increasing demand for electricity, rising costs of alternative generating facilities, a concern for security of future energy supplies, and the willingness of nuclear vendors in the industrialized world to provide financing, a number of developing countries have either begun construction of or are planning to build nuclear reactors. In addition to the four countries mentioned above, by 1980 Brazil had also installed nuclear capacity; Mexico and the Philippines have units under construction; and Egypt, Portugal, Thailand, and Turkey are currently considering building reactors. Between 1981 and 1985, developing countries' nuclear capacity will increase by about 7.0 gW. Their contribution to total electricity production would, however, be relatively modest at less than 5

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36. UN Statistical Office, World Energy Supplies, 1973-1978, table 24.

37. World Bank, Energy in the Developing Countries, p. 47.

percent.[38] As nuclear plants require lead times of approximately ten years to construct, its share is not likely to increase rapidly. Inflation in construction costs and safety and environmental problems similar to those faced by nuclear plants in the developing countries are also likely to slow the future development of nuclear power.

Noncommercial Biomass Fuels

Biomass fuels include a wide range of traditional energy sources such as firewood, crop residues, animal dung and charcoal, and newer sources such as ethanol and biogas. Most traditional fuels are predominantly produced or collected by rural households for their own use, and are therefore referred to as "noncommercial" fuels, although they may be extensively traded in organized markets in some areas. It is useful to distinguish between "noncommercial" and "commercial" biomass fuels. Noncommercial fuels generally either grow naturally or are produced as byproducts of agricultural or other activities, whereas commercial biomass fuels are produced primarily for the purpose of providing energy. We will discuss the supply of commercial biomass fuels separately in the next section.

Noncommercial fuels play a very important role in providing energy for developing countries, primarily for household cooking. In the poorest countries they may account for as much as three-quarters of total energy used. Their useful energy contribution is somewhat lower, as these fuels are generally used with much lower efficiency than commercial fuels. The World Bank estimates that "if all developing country households now using traditional fuels were to switch to kerosine, developing countries' demand for oil would rise by 15 to 20 percent."[39]

Relatively little internationally comparable data is available on the use of noncommercial fuels, which varies widely by location, season, and income class. Table 2-8 provides information on per capita consumption of noncommercial fuels in India, which may serve as an example of the role played by these fuels. In 1964, total energy provided by noncommercial fuels exceeded

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38. World Bank, Energy in the Developing Countries, pp. 47, 48.

39. World Bank, Energy in the Developing Countries, p. 38.

Table 2-8. Commercial and Noncommercial Energy Consumption in India (per capita consumption in metric tons of coal equivalents)

	1964	1977
Commercial fuels	.285	.428
Noncommercial fuels	.344	.351
Firewood	.242	.232
Dung cake	.036	.048
Vegetable waste	.066	.072

Source: Lalit K. Sen, "Rural Energy Scene in India," *Productivity* vol. 19, no. 4 (January-March, 1979) p. 656.

that provided by commercial fuels. By 1977, this was no longer the case. Firewood provided more than two-thirds of noncommercial energy used in both years. However, between 1964 and 1977 per capita consumption of firewood fell, while consumption of dung cake and vegetable wastes rose. The extent of differences between countries in the composition of noncommercial fuels is illustrated by comparing the figures for India with those from a study of Bangladesh. In Bangladesh, fuelwood accounted for only 16 percent of noncommercial energy, animal wastes accounted for 37 percent, and agricultural residues accounted for 44 percent.[40]

Collection of fuelwood in excess of growth, expansion of agricultural and grazing land, destruction by livestock and fire, and a variety of other factors are resulting in a declining supply of fuelwood in many developing countries. Villagers in many rural areas must now devote increasing time and effort to collecting fuelwood, or substitute crop residues and animal dung for fuelwood, with adverse consequences for agriculture as valuable nutrients are lost. The data in table 2-8 suggest that this may have been the case for India. Deforestation resulting from the "fuelwood crisis" is also resulting in severe environmental problems, such as erosion, drought, flooding, and desertification.

Table 2-2 presented data on countries considered by the World Bank to have "actual or potential fuelwood problems."[41] As seen from the table, a large number of developing countries fall into this category. In many countries, local fuelwood shortages may be severe, although overall growth may far exceed consumption. Thus, although Zaire consumes only about 2 percent of sustainable yield, it is experiencing serious deforestation in the area around Kinshasha.[42]

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40. Bangladesh Energy Study Figures given in David Hughart, Prospects for Traditional and Non-Commercial Fuels in Developing Countries, World Bank Staff Working Paper no. 346 (Washington, D.C., World Bank, 1979) p. 90.

41. Actual or potential fuelwood problems were defined by the World Bank as inability to sustain consumption of fuelwood through the year 2000 without damage to ecology, at a level of .75 m^3 per capita where income is \$300 or lower, falling linearly to .50 m^3 at \$600 and zero at \$900.

42. Hughart, Prospects for Traditional and Non-Commercial Fuels, p. 41.

Part of the cause of the fuelwood crisis is that in many LDCs, fuelwood is a common property resource--so that users do not pay the full costs of fuelwood use and producers do not receive the full benefits of fuelwood investments. A large share of fuelwood is collected for free from lands which are either common property where anyone may legally collect fuelwood, or from private or public forests where fuelwood collection is technically illegal but de facto uncontrolled. There is little incentive for anyone to undertake investments to increase the productivity of these areas. The benefits to any given individual of planting or protecting trees are diluted as others receive the advantages of his labor. As a result, rural villagers who collect fuelwood for their own use, as well as fuelwood sellers and charcoal makers who gather fuelwood for sale to others, cut excessive amounts of wood. These problems inherent in common property use of forest land are compounded by increasing population, which increases the demand for land for other uses, as well as the pressures upon remaining forest land.

The World Bank has estimated that on the order of 50 million hectares of fuelwood would need to be planted in developing countries over the next twenty years to satisfy projected demands for cooking and heating.[43] A number of projects have been undertaken or proposed by developing country forest services and public and private foreign donor organizations to plant trees for increased fuelwood production. However, many of these projects have failed, as villagers have shown little interest in caring for fuelwood plantations, allowing them to be burned, damaged by livestock, or cut for fuel before becoming well established. In addition, such projects tend to be very expensive, and have resulted in reforestation of only a fraction of deforested areas. Where such efforts have been successful, as in China and Korea, the strength of institutional arrangements governing individual rights and responsibilities appears to have been an important factor.

The complexity of the causes of the "fuelwood crisis," as well as the difficulties of reforestation and increasing fuelwood production, suggest that the supply of noncommercial fuelwood will continue to decline in the developing

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43. World Bank, Energy in the Developing Countries, p. 39.

countries--that both the market price of fuelwood as well as the nonmonetary "price" or labor expended in collecting a given amount of "free" fuelwood will increase. However, as the monetary and nonmonetary "price" of fuelwood increases, households, woodsellers, and industrial users will have more incentive to grow wood on privately owned or controlled land. Together with government fuelwood policies, this may help to slow the decline in output.

Nonconventional Energy Sources

The previous sections have discussed the past development of and future prospects for energy sources which are presently important in the developing countries. A wide range of other energy sources are presently of limited significance but may become important over time. These include commercial biomass fuels, solar energy and small-scale hydroelectric plants, among many others. We will refer to these energy sources as "nonconventional." As of the present, nonconventional energy sources have not been adopted in most areas due to the availability of cheaper and more convenient alternatives. However, the changing structure of energy prices, uncertainty about the availability of conventional fuels, and technological advances in production of nonconventional energy sources have improved the outlook for their production. They may eventually become important substitutes for both commercial and noncommercial fuels.

Substantial programs are underway to develop nonconventional energy resources in a number of countries. In Brazil the government has launched a major program to produce ethanol from sugar cane and cassava to substitute for gasoline as a transportation fuel. Large scale biogas programs have been launched in China and India with varying degrees of success.[44] Solar power for water heating, crop drying and photovoltaic generation of electricity is being tested in a number of countries.

The opportunities for development of nonconventional energy resources vary greatly from country to country. This variation is due to numerous factors

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44. World Bank, Energy in the Developing Countries, p. 40.

such as differences in climate, population density, and land use. These affect both resource endowment and the economic attractiveness of different energy sources. For example, estimates of annual per capita availability of dung which could be used to produce biogas vary from as low as 1 gigajoule in Egypt, Vietnam and Indonesia to 45 gigajoules in Argentina. Estimates of annual sustainable forest yield per capita vary from as low as 1 gigajoule in Kenya and Pakistan to 245 in Peru and 229 in Brazil.[45] There are similar differences in the availability of agricultural land which could be used to grow sugar cane, cassava, or other crops from which ethanol may be produced.

One difficulty in assessing the potential role of nonconventional fuels is that we do not have data on the costs of inputs such as wood and dung over different levels of production. These inputs may be available for free or for very low costs initially, perhaps as "waste" products from other activities, but as scarce land or labor resources are devoted to increased production costs will rise. In general, many nonconventional energy sources cannot yet compete with conventional energy sources on a large scale basis. The outlook for these fuels is likely to improve as further research improves the technology of nonconventional energy sources, and the costs of conventional sources continue to rise.

Summary

Developing countries face twin problems with respect to energy supplies. The first problem results from a high dependence upon imported oil for commercial energy supplies in many countries. A more than fourfold increase in the real price of oil since 1973 has aggravated the already difficult balance of payments situation of many of these countries. The second problem is the declining supply--or increasing "price"--of fuelwood, which represents the primary energy source of the poorest segments of LDC populations.

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45. Hugart, Prospects for Traditional and Non-Commercial Fuels, p. 42.

The high degree of dependence upon imported oil for commercial energy supplies may be explained by a number of factors. Prior to 1973, imported oil was relatively cheap, so that in most countries it was a preferable energy source to high cost domestic resources. Development of these resources would in many cases have necessitated large investments in transport facilities such as roads, railroads, and pipelines. In many countries, the absence of large, concentrated markets precluded the development of energy sources for which there are significant economies of scale, such as natural gas and nuclear power. Development of LDC energy resources--in particular nonoil resources--did not represent attractive investments for foreign investors, especially given depressed international markets for coal and difficulties in transportation of natural gas. Lack of managerial and technical expertise further impeded exploration for and development of commercial energy resources.

Some oil importing countries--such as larger countries with advanced industrial sectors--did develop domestic energy resources on a significant scale. Several oil-importing countries are significant oil producers, such as India and Argentina. India, Korea and Turkey are major coal producers. Mexico, Argentina and Pakistan produced large quantities of natural gas. Development of these energy sources was favored by the existence of low-cost resources and large domestic markets.

With the increase in oil prices, it has become economic for developing countries to develop higher cost domestic energy resources to reduce their dependence on imported foreign oil. However, countries vary widely in their endowments of fossil fuel reserves and hydroelectric potential. Countries with few domestic resources will remain heavily dependent upon imports. Even in those countries with energy resources, high capital costs and long lead times for construction of energy projects make rapid changes in the composition of commercial energy supplies unlikely.

The fuelwood crisis seriously affects the poorest segments of LDC populations. Fuelwood availability is declining in many areas due to increased population pressures on diminishing forest resources. The common property nature of areas from which fuelwood is gathered hinders forest protection and reduces incentives to increase fuelwood supply through planting and other forestry practices. Present efforts to reverse the fuelwood shortage are having only a limited effect, so that fuelwood problems in many areas may be expected to worsen--hastening the decline of noncommercial fuels in total energy use.

Chapter 3

THE STRUCTURE OF ENERGY DEMAND

Introduction

The composition of energy use depends upon energy demand as well as energy supply conditions. This chapter will examine the structure of energy demand in developing countries, as reflected in energy consumption patterns.

We will begin by examining the composition of energy uses in the main consuming sectors--transportation, industry, energy conversion (primarily electricity generation), and the household sector. There are important differences among these sectors. The transportation sector is heavily dependent upon oil in almost all countries. Other sectors exhibit wide variation among countries in the consumption of energy use. This variation is due to differences in industrial structure, income levels, and government policies as well as the differences in supply--reflected partly in prices--mentioned in the previous chapter. In the household sector, the share of noncommercial fuels in energy consumption declines dramatically as income rises and urbanization takes place.

Finally, we will examine the effects of economic structure upon the composition of aggregate energy use. As discussed in chapter 2, economic structure may vary greatly with factors such as the level of economic development and land, labor, capital and resource endowments. Through their effects upon economic structure, these factors affect the relative shares of each sector in aggregate energy consumption and the composition of aggregate energy use.

The Transportation Sector

In the developing countries, as in the developed countries, the transportation sector is heavily dependent upon oil. Table 3-1a shows the share of different fuels in total energy consumption in the transportation sector, for eight developing countries and four developed countries. In 1975, in all of these countries except India, the share of oil in transportation

Table 3-1a. Shares of Total Energy Consumption in Transportation, by Energy Source (percent)

Country	1967				1975			
	Coal	Oil	Gas	Electricity	Coal	Oil	Gas	Electricity
India	70.2	29.1	0.0	0.7	52.1	46.9	0.0	0.9
Kenya	11.9	88.1	0.0	0.0	3.5	96.5	0.0	0.0
Thailand	0.0	100.0	0.0	0.0	0.0	99.7	0.0	0.3
Nigeria	2.4	97.6	0.0	0.0	0.0	100.0	0.0	0.0
Turkey	21.0	78.3	0.0	0.7	8.4	91.4	0.0	0.2
Mexico	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0
Portugal	3.2	95.2	0.0	1.6	0.9	98.2	0.0	0.9
Brazil	0.4	99.6	0.0	0.0	0.1	99.9	0.0	0.0
Italy	2.2	94.9	0.7	2.2	0.4	96.0	1.4	2.2
Japan	10.6	86.0	0.0	3.4	0.1	97.1	0.0	2.8
Germany	6.7	91.0	0.0	2.3	0.9	96.8	0.0	2.3
U.S.A.	0.2	99.6	0.0	0.1	0.0	99.9	0.0	0.1

Table 3-1b. Shares of "Useful" Energy Consumption in Transportation, by Energy Source (percent)[a]

Country	1967				1975			
	Coal	Oil	Gas	Electricity	Coal	Oil	Gas	Electricity
India	31.6	65.6	0.0	2.8	17.7	79.5	0.0	2.8
Kenya	2.6	97.4	0.0	0.0	0.7	99.3	0.0	0.0
Thailand	0.0	100.0	0.0	0.0	0.0	99.5	0.0	0.5
Nigeria	0.5	99.5	0.0	0.0	0.0	100.0	0.0	0.0
Turkey	5.0	93.5	0.0	1.5	1.8	97.8	0.0	0.4
Mexico	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0
Portugal	0.6	96.4	0.0	2.9	0.2	98.2	0.0	1.6
Brazil	0.1	99.9	0.0	0.0	0.0	100.0	0.0	0.0
Italy	0.4	95.0	0.7	3.9	0.1	94.6	1.3	3.9
Japan	2.3	91.3	0.0	6.5	0.0	95.0	0.0	5.0
Germany	1.4	94.3	0.0	4.3	0.2	95.7	0.0	4.1
U.S.A.	0.0	99.7	0.0	0.3	0.0	99.8	0.0	0.1

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December, 1978, vol. II (Paris, OECD, 1979); IEA, Energy Balances of OECD Countries (Paris, OECD, 1976, 1980).

[a]"Useful" energy was calculated by multiplying coal use by .044, oil & gas use by .22, and electricity use by .40. These efficiences were taken from William D. Nordhaus, "The Demand for Energy: An International Perspective," in William D. Nordhaus, ed., Proceedings of the Workshop on Energy Demand, May 22-23, 1975 (Laxenburg, Austria, International Institute for Applied Systems Analysis, 1976) p. 527.

sector energy consumption was over 90 percent. This heavy dependence upon oil reflects the predominance of oil-using automobiles, trucks, locomotives, ships, and aircraft in transportation.

Two exceptions to this pattern are provided by India and Turkey, which use substantial quantities of coal in steam locomotives. In India, coal accounted for over one-half of the total energy used in the transportation sector in 1975. However, coal-powered steam locomotives are much less energy efficient than are diesel locomotives. If an adjustment is made to take into account these differences in efficiency (see table 3-1b), the effective contribution of coal to transportation energy consumption falls sharply--instead of providing 52 percent of total energy consumed in transportation in India in 1975, the share falls to 18 percent.

In both India and Turkey the role of coal in transportation is declining as steam locomotives are withdrawn from service and not replaced. The fact that coal retained such a substantial role in transportation in India is due to domestic railway equipment production decisions. In order to utilize existing production capacity for steam locomotives, the Indian railways continued to make steam engines until 1971. Since then no new steam engines have been made, which means that the role of coal will continue to decline, and India, like the other countries, will become highly dependent on liquid fuels in the transportation sector.[46]

An alternative to the use of oil is the use of electricity for rail lines. However, to be economic, this requires a high traffic density as well as a cheap source of electricity, such as hydropower. In general, the lower the level of development, the lower will be traffic density, except for urban passenger transportation. For the developing countries in table 3-1, the share of electricity in energy consumed in transportation was less than 1 percent. Thus in most countries, the transportation sector appears likely to remain heavily dependent upon oil, with growth in this sector reflected in increasing demand for oil.

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46. Ashok V. Desai, "Interfuel Substitution in the Indian Economy," Discussion Paper from the Center for Energy Policy Research, D73-B (Washington, D.C., Resources for the Future, July 1981) pp. 22-25.

The Industrial Sector

Table 3-2a presents data on the shares of different fuels in industrial sector energy use. In 1975, in seven of the eight developing countries shown in table 3-1a, oil was the most important fuel, accounting usually for well over half of industrial energy consumption. In all of the countries, electricity accounted for between 7 and 20 percent of industrial energy consumption. There was wider variation in the share of coal, which among developing countries exceeded 12 percent only in India and Turkey, and in the share of gas, which was significant only in Nigeria and Mexico. The share of noncommercial fuels was significant only in Kenya, Thailand and Brazil where they provided about one-fifth of total consumption.

As discussed in chapter 1, the efficiencies with which different fuels are used varies considerably. Electricity is used with the highest efficiency followed by gas and oil, by coal and finally by noncommercial fuels. If we take account of differing efficiencies by comparing "useful" energy contributions (table 3-2b), the share of electricity is increased, while the share of noncommercial fuels becomes very small.

The shares of the different fuels used in the industrial sector changed considerably over the eight-year period between 1967 and 1975. In general, the shares of coal and noncommercial fuels in the total fell and the shares of oil and electricity rose. As discussed in chapter 2, one cause of the shift away from coal appears to have been changing supply conditions, reflected in a declining real price of oil and expanding electricity generation capacity and lower tariffs. In addition, industrial energy demand was shifting in favor of oil and electricity. New industrial technologies during the 1950's and 1960's tended to use oil or electricity, due to their cheapness and flexibility. Rapid industrial sector growth following this technological shift resulted in generally lower industrial dependence on coal in the developing countries than in the older industrial economies.

Data on noncommercial fuel consumption in industry is likely to be less reliable than data for other fuels. In addition, definitions of "industry" differ widely. Thus the inclusion of small-scale handicraft industries in

Table 3-2a. Shares of Total Energy Consumption in Industry, by Energy Source (percent)[a]

	1967					1975				
Country	Coal[b]	Oil	Gas	Electricity	Noncommercial fuels	Coal[b]	Oil	Gas	Electricity	Noncommercial fuels
India	83.7	12.0	0.2	0.8	3.4	78.8	7.7	1.0	8.3	4.2
Kenya	8.3	0.0	0.0	0.0	91.7	0.7	68.2	0.0	12.3	18.9
Thailand	1.7	78.1	0.0	0.0	20.2	0.3	56.8	0.0	18.3	24.5
Nigeria	23.9	50.9	15.3	8.4	1.4	8.5	67.6	14.4	8.7	0.8
Turkey	44.4	43.5	-0.5	12.5	0.0	22.6	59.5	0.0	17.8	0.0
Mexico	9.6	32.1	47.6	5.4	5.4	11.4	31.9	46.3	7.2	3.3
Portugal	34.2	42.5	0.0	23.3	0.0	9.6	70.7	0.0	19.7	0.0
Brazil	9.3	50.9	3.8	7.9	28.1	6.9	58.6	2.8	13.1	18.6
Italy	16.6	49.6	17.4	16.5	0.0	10.4	53.6	21.6	14.4	0.0
Japan	31.7	48.6	1.8	17.8	0.0	25.5	53.2	1.7	19.6	0.0
Germany	46.3	37.1	2.7	13.9	0.0	21.1	40.8	22.9	15.3	0.0
U.S.A.	22.9	11.4	49.9	15.7	0.0	21.4	22.1	41.0	15.7	0.0

Sources: See table 3-2b.

Table 3-2b. Shares of "Useful" Energy Consumption in Industry, by Energy Source (percent)[a]

Country	1967					1975				
	Coal[b]	Oil	Gas	Electricity	Non-commercial fuels	Coal[b]	Oil	Gas	Electricity	Non-commercial fuels
India	84.0	13.7	0.2	1.1	1.0	77.4	8.6	1.2	11.6	1.2
Kenya	24.1	0.0	0.0	0.0	75.9	0.7	76.9	0.0	17.1	5.3
Thailand	1.8	92.3	0.0	0.0	6.0	0.4	66.1	0.0	26.4	7.1
Nigeria	21.2	51.5	16.5	10.5	0.4	7.3	66.7	15.1	10.7	0.2
Turkey	39.9	44.7	-0.5	15.9	0.0	19.5	58.7	0.0	21.8	0.0
Mexico	8.5	32.4	51.0	6.7	1.4	9.9	31.6	48.8	8.9	0.8
Portugal	29.5	42.0	0.0	28.5	0.0	8.1	68.4	0.0	23.5	0.0
Brazil	10.2	63.7	5.1	12.3	8.8	6.9	66.2	3.4	18.3	5.3
Italy	14.1	48.2	18.0	19.8	0.0	8.8	51.8	22.2	17.2	0.0
Japan	27.7	48.4	1.9	22.0	0.0	21.9	52.4	1.9	23.8	0.0
Germany	41.4	38.0	2.9	17.6	0.0	18.1	39.8	23.7	13.4	0.0
U.S.A.	19.3	11.0	51.0	18.7	0.0	18.0	21.3	42.1	18.6	0.0

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979).

[a]"Useful" energy was calculated by multiplying coal use by .7, oil use by .8, gas use by .85, electricity use by .99, and noncommercial energy use by .2. The efficiency for noncommercial fuels represents a guess by the author. The efficiencies for commercial fuels were taken from William D. Nordhaus, "The Demand for Energy: An International Perspective," in William D. Nordhaus, ed., Proceedings of the Workshop on Energy Demand, May 22-23, 1975 (Laxenburg, Austria, International Institute for Applied System Analysis, 1976) p. 527.

[b]The energy content of "secondary solid fuels" was converted to that of "primary solid fuels" based upon the efficiency of production of secondary solid fuels from primary solid fuels.

"industry" might increase the share of noncommercial fuels in total "industrial" use considerably.

The role of noncommercial fuels in industrial energy consumption appears to be closely related to resource endowments. In 1975, of the countries listed in table 3-2a, only Kenya, Thailand and Brazil used significant quantities of noncommercial fuels in industry. All three of these countries have major forest resources. In addition, as in industrial countries, some industries use traditional fuels which are by-products of their main activity to provide energy. Bagasse, for example, is used as an energy source in distilleries and waste wood is used in the manufacture of pulp and paper.

Transport costs are a major consideration in determining industrial use of noncommercial fuels. As these fuels are bulky, with lower energy content in relation to volume, they tend to be consumed relatively close to their point of production. Thus a major industrial use of noncommercial fuels in Brazil is for steel production in areas remote from coal supplies but close to major forests.[47]

Finally, structural changes within the industrial sector affected the composition of energy use in industry. To begin with, growth in modern industrial activity led to a shift from traditional to commercial fuels. Industrial development also affected the mix of commercial fuels. Major industrial development took place over this period in industries such as iron and steel, cement, aluminum, pulp and paper, fertilizers and petroleum refining (see table 3-3). Each of these activities tends to require to some extent specific types of fuels. For example, iron and steel require coal,[48] aluminum requires electricity and petrochemicals and petroleum refining are heavily

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47. Henri Meyers, "Charcoal Ironmaking: A Technical and Economic Review of Brazilian Experience." (New York, United Nations Industrial Development Organization, November 8, 1978).

48. Formerly, coal accounted for virtually all of the energy used in iron and steel, but recent developments in the technology of coal production have reduced the share of coal in energy used in iron and steel production to about 60 percent. Thus the significance of changes in iron and steel production for the composition of industrial fuel use has declined.

Table 3-3. Output of Selected Industrial Products

(000 metric tons)

Product/Country	1961	1967	1970	1973	1977
Steel					
Argentina	442	1348	1859	1995	2676
Brazil	2443	3734	5390	7149	11165
Columbia	181	207	239	263	210
India	4084	6440	6286	7354	9836
Korea	66	300	481	1157	2737
Mexico	1725	3059	3846	4652	5529
Cement					
Argentina	2906	3552	4770	5186	6030
Brazil	4711	6405	9002	13398	20528
Columbia	1572	2146	2757	3221	3300
India	8246	11302	13956	15016	19173
Korea	511	2441	5782	8175	14198
Mexico	3035	5997	7267	9918	13328
Aluminum					
Argentina	--	--	--	--	--
Brazil	20	38	48	97	167
Columbia	--	--	--	--	--
India	18	96	161	154	184
Korea	--	--	15	17	18
Mexico	--	22	34	39	43
Paper & paper board					
Argentina	364	469	640	767	766
Brazil	440	841	1116	1460	2146
Columbia	65	145	220	278	281
India	424	66[illegible]	823	796	936
Korea	34	97	228	392	927
Mexico	434	648	857	1074	1290
Fertilizers[a]					
Argentina	5	11	34	29	30
Brazil	13	8	22	114	232
Columbia	10	40	61	81	72
India	193	360	838	1050	2000
Korea	38	150	386	447	669
Mexico	83	173	330	376	611
Petroleum refining[b]					
Argentina	18230	21650	23980	31310	33205
Brazil	14930	18590	27300	42600	57500
Columbia	3920	6540	6700	8100	8670
India	8480	17460	23290	24570	32000
Korea	--	2510	10750	19750	25185
Mexico	19680	24630	29600	38000	48650

Source: United Nations, Statistical Yearbook (New York, UN) (various issues).

[a] Fertilizer data in years: 1962/63, 1967/68, 1970/71, 1973/74, 1977/78.

[b] 1962.

dependent upon petroleum. Development of these industries is reflected in increased shares of these fuels in industrial energy consumption. In turn, the supply of these fuels influenced the structure of industrial development: cheap hydroelectric power was required for the aluminum industry, for example.

Development of fuel-specific industries such as steel also had indirect effects upon the composition of energy use in the industrial and other sectors. In India, for example, low quality coal mined in the production of high quality coal for the iron and steel industry was used for power generation.[49]

The Energy Conversion Sector

In both the developing and the developed countries, a significant share of total energy consumption results from "losses" in converting one form of energy into another. Table 3-4 presents the shares of total energy use consumed in the energy conversion sector in selected countries in 1975, by fuel. There is wide variation among developing countries in the sizes of these shares, which range from 0 percent to as high as 92 percent for coal, 26 percent for oil, and 52 percent for gas. While electricity generation accounts for most energy losses in conversion, there are also conversion losses in refining petroleum fuels from crude oil, producing secondary solids, liquid fuels, and gases from primary solids, and producing liquid fuels from gases. Although conversion from one energy source to another results in an accounting "loss" of energy, the conversion is to a more useful and valuable form of energy.

Conversion technologies are mostly fuel-specific with the exception of electricity generation, where there is considerable variation in the fuels used, as illustrated for selected countries in table 3-5. Since the technology of electricity generation is very flexible, the choice of fuels is determined primarily by supply conditions. Thus gas is used to generate electricity in Mexico and coal is used in India and Turkey; in other countries where these fuels are not produced they play only a minor role in electricity generation. As mentioned in chapter 2, the proportion of hydroelectricity in total energy used in electricity generation is higher in the developing than in the

49. Desai, "Interfuel Substitution," p. 17.

Table 3-4. Shares of Total Commercial Energy Requirements Consumed in the Energy Conversion Sector, by Energy Source, 1975[a]

Country	Coal	Oil	Gas
India	27.9	15.8	45.6
Kenya	0.0	13.7	b
Thailand	91.9	18.1	b
Egypt	3.2	16.2	-6.4[c]
Nigeria	0.8	1.5	43.9
Korea	20.8	23.1	b
Columbia	12.5	22.4	51.7
Turkey	18.6	16.4	b
Mexico	8.9	25.8	11.1
Portugal	32.6	21.3	b
Brazil	39.8	5.7	15.4
Italy	40.0	25.9	11.1
Japan	33.0	36.7	13.3
Germany	68.2	10.3	27.9
USA	76.1	12.4	31.1

Sources: International Energy Agency, Basic Energy Statistics and Energy Bálances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, Volume II, (Paris, OECD, 1979); IEA, Energy Balances of OECD Countries, 1974-1976 (Paris, OECD, 1978).

[a]The energy conversion sector includes electricity generation, gas manufacture, refineries, other transformations, energy sector use and loss, transfers, and statistical difference.

[b]Not applicable.

[c]A negative sign indicates production of the fuel from other energy sources.

Table 3-5. Shares of Total Energy Used in Electricity Generation, by Energy Source (percent)

	1967				1975			
Country	Coal	Oil	Gas	Hydro and nuclear power[a]	Coal	Oil	Gas	Hydro and nuclear power[a]
India	52.4	5.9	1.0	40.7	53.7	6.7	0.5	39.2
Kenya	0.0	0.0	0.0	100.0	0.0	31.8	0.0	68.2
Thailand	7.8	43.2	0.0	49.0	4.5	49.7	0.0	45.8
Turkey	45.6	18.9	0.0	35.6	32.8	33.5	0.0	33.7
Mexico	0.4	16.4	23.2	60.0	0.5	43.3	17.7	38.5
Portugal	6.3	4.4	0.0	89.4	6.1	32.8	0.0	61.1
Brazil	6.8	7.6	0.7	84.8	3.3	4.3	1.4	91.0
Italy	11.5	34.0	4.1	50.3	5.7	55.9	5.3	33.2
Japan	35.7	33.5	0.0	30.8	10.9	61.6	3.9	23.7
Germany	78.6	9.6	2.2	9.6	63.0	7.1	17.2	12.8
USA	53.2	8.0	22.0	16.8	46.5	15.8	15.2	22.5

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries 1976-1977 Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979); International Energy Agency, Organisation for Economic Co-operation and Developing, Energy Balances of OECD Countries, 1950-1974, 1974-1978 (Paris, IEA/OECD, 1976, 1980).

[a]Calculated in terms of the fossil fuel equivalent that would be needed to produce the same amount of electricity assuming a conventional power plant operating at 28 percent efficiency.

developed countries (see table 2-7). However, for all of the developing countries in table 3-5 except Brazil, this share declined between 1967 and 1975, while the share of oil rose.[50]

In addition to resource endowments, other circumstances specific to individual countries affected the mix of fuels used in electricity generation. In India, for example, impetus was given to coal-fired thermal power generation in the early sixties by the expansion of the steel industry. The steel industry required high-quality, low-ash coal, while lower quality coal mined at the same time was useful only for power generation. Expansion of fuel oil use as a supplementary fuel in electricity generation was partly related to demand factors. Fuel oil is preferable to coal for generating plants when the load factor is low, or when there are fluctuations in load. These fluctuations increased in the seventies when the proportion of agricultural demand--which was highly seasonal and varied considerably from day-to-day--increased, resulting in a rise in fuel oil consumption.[51]

The Household Sector

The "household" sector is difficult to define precisely, especially in developing countries. Household activities merge with a variety of agricultural, commercial and workshop activities. Energy data for developing countries generally lump together energy used in these different activities, making the household sector in effect a residual sector. In this section we will address the composition of energy use in this wide range of activities. However, we will focus our attention primarily upon energy used in cooking--the most significant use of energy by households.

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50. This trend was not observed for the developing countries as a whole, for which the share of hydroelectricity increased from 43.5 percent to 43.8 percent over this period (United Nations Statistical Office, World Energy Supplies, 1973-1978, Statistical Papers Series J, no. 22 (New York, UN, 1979), pp. 246, 275; and United Nations Statistical Office, World Energy Supplies, 1950-1974, Statistical Papers Series J, no. 19 (New York, UN, 1976), pp. 596, 707.

51. Desai, "Interfuel Substitution," p. 19.

A very wide range of fuels is used in the household sector. Traditional fuels--fuelwood, charcoal, and animal crop wastes--are most important in rural areas, while commercial fuels such as coal, gas, kerosine, and electricity are most important in urban areas. However, some quantities of commercial fuels, such as kerosine for lighting, are used widely in rural areas, while fuelwood and charcoal are widely traded even in large cities.

Table 3-6a presents data in the composition of energy use in the residential, agriculture, commercial, and public service sectors, for selected developing and developed countries. Aggregate data on noncommercial fuel use are available for only a few countries, and are likely to be less reliable than those for other fuels. However, these data show that the share of noncommercial fuels in household sector energy use can be very high--90 percent or more--particularly in the poorer countries.

As in other sectors, noncommercial fuels are used in the household sector at lower efficiencies than commercial fuels. Only a low share of the heat produced in burning traditional fuels is delivered to the cooking process--roughly 5 to 15 percent. In contrast, the efficiencies with which many commercial fuels are used are much higher, around 50 percent for kerosine stoves and 60 percent for gas stoves (see table 3-7). As shown in table 3-6b, these lower efficiencies result in a lower share of traditional fuels in "useful" energy produced for the household sector. However, in several countries--India, Kenya, Nigeria, and Brazil--this share remains substantial.

In terms of both gross energy consumption or "useful" energy, the share of noncommercial fuels in household energy consumption has been declining over time (see again tables 3-6a and 3-6b). This decline is a result of changes in both supply as well as demand conditions for both commercial and noncommercial fuels.

As discussed in chapter 2, both the monetary and the nonmonetary price (such as time spent in collecting fuelwood) of traditional fuels have been increasing in many developing countries, due to increased population pressure upon diminishing common property resources. As a result, per capita consumption has declined, and households have substituted commercial fuels for traditional fuels.

Table 3-6a. Shares of Total Energy Consumption in Agriculture, Commercial, Public Service, and Residential Sectors, by Energy Source

(percent)[a]

Country	1967 Coal	1967 Oil	1967 Gas	1967 Electricity	1967 Non-commercial fuels	1975 Coal	1975 Oil	1975 Gas	1975 Electricity	1975 Non-commercial fuels
India	0.4	11.2	0.1	2.4	86.0	5.7	14.7	0.1	4.2	75.3
Kenya	0.0	2.5	0.0	0.0	97.5	0.0	8.4	0.0	1.6	90.0
Thailand	0.0	82.4	0.0	0.0	17.6	0.0	89.5	0.0	7.6	2.9
Nigeria	0.0	1.6	0.0	0.2	98.3	0.0	2.8	0.0	0.6	96.6
Turkey	35.0	58.2	1.5	5.3	0.0	70.0	27.3	0.3	2.4	0.0
Mexico	0.0	44.2	5.5	8.9	41.4	0.0	49.5	6.8	17.0	26.8
Portugal	26.7	55.8	3.5	14.0	0.0	0.9	64.2	3.8	31.1	0.0
Brazil	0.0	9.3	0.5	3.7	86.5	0.0	15.3	0.6	10.7	73.3
Italy	18.6	60.6	9.2	11.6	0.0	3.1	67.0	18.7	11.2	0.0
Japan	15.0	63.5	8.0	13.5	0.0	6.9	64.5	9.8	18.8	0.0
Germany	35.4	48.7	5.9	10.0	0.0	10.2	62.2	12.3	15.1	0.0
U.S.A.	3.9	37.9	42.6	15.6	0.0	1.2	31.0	43.9	23.9	0.0

Sources: See table 3-6b.

Table 3-6b. Shares of "Useful" Energy Consumption in Agriculture, Commercial, Public Service, and Residential Sectors, by Energy Source

(percent)[a]

Country	1967					1975				
	Coal	Oil	Gas	Electricity	Noncommercial fuels	Coal	Oil	Gas	Electricity	Noncommercial fuels
India	0.4	37.9	0.4	12.6	48.6	5.3	40.9	0.2	18.7	34.9
Kenya	0.0	13.5	0.0	0.0	86.5	0.0	32.4	0.0	9.8	57.8
Thailand	0.0	96.6	0.0	0.0	3.4	0.0	87.7	0.0	11.8	0.5
Nigeria	0.0	8.7	0.0	1.4	89.9	0.0	14.1	0.0	4.8	81.2
Turkey	14.6	72.7	2.2	10.5	0.0	42.6	49.9	0.7	6.8	0.0
Mexico	0.0	61.7	9.0	19.7	9.6	0.0	55.7	8.9	30.3	5.0
Portugal	9.8	61.4	4.5	24.3	0.0	0.3	54.3	3.7	41.7	0.0
Brazil	0.0	30.6	2.1	19.6	47.7	0.0	33.9	1.6	37.5	27.0
Italy	6.5	63.3	11.1	19.1	0.0	1.0	62.2	20.3	16.6	0.0
Japan	5.0	64.0	9.4	21.6	0.0	2.1	59.8	10.5	27.5	0.0
Germany	14.2	58.5	8.3	19.0	0.0	3.3	59.8	13.8	23.0	0.0
U.S.A.	1.1	33.3	43.7	21.8	0.0	0.3	25.7	42.5	31.4	0.0

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979); International Energy Agency, Organi ation for Economic Co-Operation and Development, Energy Balances of OECD Countries, 1950-1974, 1974-1978 (Paris, IEA, OECD, 1976, 1980).

[a]"Useful" energy was calculated by multiplying coal use by .2, oil use by .6, gas use by .7, electricity use by .95, and noncommercial energy use by .1. The efficiency for noncommercial fuels represents a guess by the author. The efficiencies for commercial fuels were taken from William D. Nordhaus, "The Demand for Energy: An International Perspective," in William D. Nordhaus, ed., Proceedings of the Workshop on Energy Demand, May 22-23, 1975 (Laxenburg, Austria, International Institute for Applied Systems Analysis, 1976), p. 527. Data on noncommercial fuels were not available for Turkey, Portugal, Italy, Japan, Germany, and the U.S.A. Hence these shares are presented as 0, even though at least some noncommercial fuels were consumed in all of these countries.

Table 3-7. Average Efficiency of Utilization of Selected Cooking Fuels in India

	Energy content (MJ/kg)	Utilized energy (MJ/kg)	Efficiency (percent)
LP gas	44	27.7	63
Kerosine			
in pressure stove	43	24.3	56
in wick stove	43	18.0	42
Soft coke	40	4.0	10
Coal	27	2.7	10
Firewood			
closed hearth	15	2.6	16
open hearth	15	1.9	13
Twigs and straw			
closed hearth	10	1.6	16
open hearth	10	1.3	13
Dungcake	10	0.8	8

Source: Ashok V. Desai, "Interfuel Substitution in the Indian Economy," discussion paper from the Center for Energy Policy Research, D-73B (Washington, D.C., Resources for the Future, July 1981) p. 50.

Supply conditions vary greatly with location. Commercial fuels may not be available or may be only spasmodically available in rural areas, leaving little alternative to locally available traditional fuels. Conversely, in towns and cities there may be no access to noncommercialized or "free" traditional fuels. Where traditional fuels such as fuelwood or charcoal are available commercially, their prices will reflect transportation costs. Compared to fuelwood, charcoal has a low weight relative to value and may be transported profitably over greater distances. Thus the farther removed an urban area is from forested areas, the higher will be the price (or lower the availability) of both fuelwood and charcoal, although the price of charcoal will rise relatively less rapidly than the price of fuelwood.

Supply constraints for traditional fuels in urban areas help to explain the rising proportion of commercial fuels in total household energy consumption. Between 1960 and 1980 urban population as a percentage of total population increased from 17 to 21 percent in low-income countries and from 37 to 51 percent in middle-income countries; the percentage of urban population in cities over 500,000 increased from 24 to 45 percent in low-income countries and from 36 to 49 percent in middle-income countries.[52] Thus a growing proportion of the total population of developing countries is living in areas where they have no access to traditional fuels and must instead use commercial fuels.

As in other sectors, household sector fuel choices are influenced by overall costs of fuel, capital (stoves), and labor (time), rather than by fuel costs alone. Commercial fuels such as kerosine and bottled gas appear expensive on a heat-content basis, compared with noncommercial fuels. In addition, costs of stoves for commercial fuels are higher. However, the higher efficiencies with which these fuels are burned, as well as their great convenience, tend to lower their effective costs as cooking fuels, compared with noncommercial fuels.

As income rises, demand for fuels in the household sector shifts from traditional to commercial fuels. These trends are illustrated in table 3-8 for Mexico City and Nairobi. Although these data reflect energy use by different

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52. World Bank, World Development Report, 1980 (Washington, D.C., World Bank, August 1980) pp. 148-149.

income groups at one point in time, they serve to indicate changes which might occur for a given group over time as income rises. The data apply to urban areas; use of noncommercial fuels for a given income group is likely to be relatively higher in rural areas.

One reason for this shift from noncommercial to commercial fuels with rising income is the greater convenience of commercial fuels. As incomes rise, households place relatively greater value on convenience compared to the possible savings from using cheaper fuels. Another reason for the shift is greater household demand for services requiring commercial fuels, such as lighting and appliances. In both rural and urban areas, at the lowest income levels, energy is mainly used for cooking. At higher levels of income, the range of household energy demand expands to uses such as lighting, water heating, ironing, radios and fans.

Among commercial fuels, in most countries oil-based fuels (mostly kerosine) and electricity are most important in household sector consumption as shown in table 3-6a. Where locally available, other fuels may be important, such as coal in Turkey and gas in Mexico. The share of electricity rose dramatically between 1967 and 1975. This may be attributed to substitution of electricity for other fuels and increased demand for lighting and electric appliances, associated with rising incomes, as well as to expanding electricity supply. As suggested by table 3-8, fuels such as kerosine may play a transitional role between noncommercial fuels and electricity. At low income levels, kerosine tends to be a superior good for which consumption rises with income, replacing wood. As income continues to rise, kerosine becomes an inferior good, being replaced by electricity and gas.[53]

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53. Several econometric studies, quoted in Joy Dunkerley, John E. Jankowski, Jr., Malcolm Gillis, R.K. Pachauri, Pierre Ehrlich et al., and Robert Kahn, "Assessment of Energy Demand Projections for Selected Developing Countries," Draft prepared for Office of Long-Range Assessment and Research, U.S. Department of State (Washington, D.C., Resources for the Future, August 1980) have found varying income elasticities for kerosine. Summers reported a GDP elasticity of 1.59 for Indonesia (1.0 if a price term is included). Strout found an income elasticity of .78 based on a cross-sectional study (pp. 4.19, 4.46, 4.47). Pindyck found zero and even negative elasticities for several countries. These results can all be accommodated within the hypothesis that kerosine is a transitional fuel.

Table 3-8. Wood and Charcoal, Oil Based Fuels, and Electricity as Percentages of Total Energy Consu[illegible] for Direct Residential Use, Mexico City and Nairobi

Income group	Mexico City			Nairobi		
	Wood and charcoal	Oil based fuels	Electricity	Wood and charcoal	Oil based fuels	Electricity
Low	28	55	17	67	33	0
Lower middle	0	63	37	67	24	9
Middle	0	53	47	20	26	54
Upper middle	0	49	51	10	12	78
High	0	43	57	5	1	95

Source: G. McGranahan, S. Chubb, R. Nathans, and O. Mbeche, "Patterns of Urban Household Energy Use in Developing Countries: The Case of Nairobi," Draft (Stony Brook, The State University of New York, The Institute for Energy Research, February 1979), p. 67.

The Composition of Total Energy Use

Given the composition of energy use in individual sectors, the composition of total energy use will be determined by the relative shares of each sector in total energy use. Previous sections discussed factors affecting the "within-sector" composition of energy use; in this section we will discuss factors affecting the "between-sector" distribution of energy use. Table 3-9 presents the shares of the four sectors discussed above in total commercial energy consumption for 1967 and 1975 for selected developing and developed countries. For both the developing and the developed countries, there is a wide range in the shares of each sector. In 1975, among developing countries, the share of transportation ranged from 19 to 46 percent; the share of industry ranged from 15 to 41 percent; the share of households and related sectors ranged from 8 to 46 percent; and the share of electricity generation ranged from 9 to 25 percent. For those countries in the table, the share of the household sector was in general somewhat higher among the developed countries; otherwise no definite trends were apparent. There was no consistent trend over time in the relative sizes of different shares among the developing countries.

What factors determine the sectoral distribution of energy use? We may distinguish between three interrelated factors. These are fuel efficiency within sectors, energy intensity within sectors, and the distribution of economic activity between sectors. We will discuss these factors briefly below.

The lower fuel efficiency is within a sector, the greater will be energy consumption in that sector. For example, coal burns less efficiently than oil, providing less "useful" energy for a given level of total energy consumption. Thus, the greater the dependence of a sector (relative to other sectors) upon coal, the greater will be the share of the sector in total energy consumption. Examples of this effect are provided by table A-2 (see appendix A) and table 3-9. As shown in table A-2, coal use in Turkey in 1975 was concentrated in "other final sectors"--households and related sectors. Coal use in Kenya was concentrated in the transportation sector. As shown in table 3-9, the coal-dependent sectors in these two countries accounted for much larger shares of total commercial energy consumption than in other countries.

Table 3-9. Percent of Total Commercial Energy Consumption by Sector[a]

Country	Transportation 1967	Transportation 1975	Industry 1967	Industry 1975	Household or related sectors 1967	Household or related sectors 1975	Electricity generation 1967	Electricity generation 1975	All other uses 1967	All other uses 1975
India	23.5	19.0	34.9	41.0	6.2	10.2	16.7	22.9	18.7	6.9
Kenya	(c)	45.7	(c)	15.1	(c)	18.8	(c)	12.7	(c)	7.7
Thailand	11.8	34.5	16.5	21.1	18.0	19.1	17.8	16.8	13.3	8.6
Nigeria	28.6	36.9	27.3	23.4	12.5	8.2	17.2	9.4	14.4	22.1
Turkey	28.2	19.7	21.4	15.7	26.1	45.5	12.5	10.1	11.8	9.0
Mexico	21.2	21.4	37.2	40.0	8.6	8.4	10.6	13.4	22.3	16.8
Portugal	25.6	27.4	24.7	28.9	17.8	12.8	22.3	18.4	9.6	12.5
Brazil	29.0	28.3	23.2	24.7	10.2	11.3	24.4	25.2	13.3	10.5
Italy	15.1	15.0	33.3	34.8	20.2	25.7	17.5	16.1	13.9	8.5
Japan	11.8	12.5	38.5	37.8	15.6	17.8	17.9	20.6	16.2	11.4
Germany	11.8	13.6	30.0	29.7	27.4	29.4	15.6	17.4	15.3	9.9
USA	22.7	25.0	26.3	21.3	25.4	24.7	15.6	18.9	10.0	10.2

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, volume II (Paris, OECD, 1979); International Energy Agency, Energy Balances of OECD Countries, 1974-1976 (Paris, OECD, 1978); and Organization for Economic Co-operation and Development, Energy Balances of OECD Countries, 1960-1974 (Paris, OECD, 1976).

[a] Includes residential, agriculture, commercial, and public service sources.

[b] Includes energy use not allocated by sector.

[c] 1967 figures not presented as over 50 percent of total energy use was unallocated by sector.

Energy intensity within sectors may vary widely. Low vehicle gas mileage in the transportation sector will increase the energy intensity of the transportation sector and the share of transportation in total energy consumption. The energy intensity of industry is affected by the availability and quality of other inputs, such as capital, labor and raw materials. If capital is scarce and labor is plentiful, industry will tend to be less energy intensive, lowering the share of industry in total energy consumption.

The distribution of economic activity among sectors is determined by the path and level of economic development, which is affected by a wide spectrum of economic, political, and social factors. These vary greatly among countries, making it difficult to generalize about aggregate economic structure or its effects upon energy use. One important trend which occurs with development is an increase in the share of output of the industrial sector relative to the agricultural sector. This shift is reflected in rapidly increasing energy use, since industry is more energy intensive than agriculture. The effects of industrialization upon the structure of commercial energy use are less clear. Transportation of goods and people tends to increase along with industrialization. Similarly, rising per capita income accompanying industrialization increases household and service activities which use commercial fuels. However, the relative growth rates of these sectors will vary widely among countries, so that their relative shares in commercial energy consumption may rise or fall with industrialization. For example, one study found that energy consumed in transportation by households was much lower in Nairobi than in Mexico City, for all income levels. This disparity was attributed to "differences in city-size, degree of urban sprawl, level of urban congestion, and the resulting difference in travel patterns.[54]

Summary

We may summarize the structure of aggregate energy demand as follows. First, two trends have occurred over time in the composition of energy use in

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54. G. McGranahan, S. Chubb, R. Nathans, and O. Mbeche, "Patterns of Urban Household Energy Use in Developing Countries: The Case of Nairobi." Draft (Stony Brook, The State University of New York, The Institute for Energy Research, February 1979) p. 30.

most countries. The share of coal in energy consumption has declined as both supply and demand conditions have shifted in favor of other fuels. The share of noncommercial fuels has declined with an increase in the share of "modern" economic activities in total output, with rising incomes, and with urbanization.

Secondly, there is great variation between countries in the composition of energy use within sectors. An exception is the transportation sector, which is heavily dependent upon oil. Much of the variation in the composition of energy use within sectors appears to result from differences in supply conditions. The shares of coal, natural gas, and electricity depend greatly on the extent to which countries are endowed with coal and natural gas resources and hydroelectric potential. These effects of supply conditions are similarly reflected in the composition of aggregate energy use, although the common dependence of most countries' transportation sectors upon oil dampens this effect.

Thirdly, there is considerable variation among countries in the relative shares of the four sectors we have discussed--transportation, industry, households and energy transformation--in total energy consumption. This variation results from differences among countries in the level and path of economic development, as well as differences among countries in the relative energy intensity and energy efficiency of different sectors.

These findings have two important implications for the future composition of energy use in developing countries. First, transportation sectors appear likely to remain heavily dependent upon oil use. Energy conservation in transportation would serve to reduce the share of oil in total energy consumption. Secondly, technologically there is considerable scope for varying the composition of energy use in the nontransportation sectors. However, in the short run, changes are limited by the requirements of the existing capital stock. In the long run, changes are limited by countries' abilities to produce or import various energy sources. Countries without resources of coal, natural gas, hydroelectricity, or biomass will face much greater difficulties in reducing the share of oil in energy consumption than those countries with domestic resources.

The changes in final energy consumption in Brazil and India between 1967 and 1975 (see tables 3-10 and 3-11) serve to illustrate these points. Of the 32.4 million mtoe increase in energy consumption in Brazil over this period, 24.6 million mtoe, or 76 percent was accounted for by oil. Forty-six percent of the increase in oil consumption, or 35 percent of the increase in total energy consumption, resulted from increased oil consumption in transportation. Oil also accounted for most of the increases in energy consumption in the industrial and household sectors. In contrast, of the 24.6 million mtoe increase in final energy consumption over this period in India, only 7.7 million mtoe, or 31 percent, was accounted for by oil. Over half of the increase in oil consumption occurred in the transport sector. Oil accounted for less than 3 percent of the increase in industrial sector energy consumption and less than one-quarter of the increase in household energy consumption.

Thus, the much smaller share of oil in the increase in energy consumption in India may be attributed both to slower relative growth in transportation energy consumption as well as a smaller share of oil in the nontransport sectors. The latter may be attributed both to favorable supply conditions for coal in India as well as to government policies favoring the use of coal. We will discuss government policies affecting the composition of energy use in the next chapter.

Table 3-10. Brazil: Changes in Final Energy Consumption, 1967-75[a]

(million metric tons of oil equivalent)

Fuels	Industry	Transportation	Household and related sectors	Other[c]	Total
Coal	0.6	--	--	--	0.5
Oil	7.6	11.2	2.5	2.9	24.6
Gas	0.2	--	0.1	--	0.3
Electricity	2.0	--	2.4	--	4.0
Noncommercial	1.2	--	1.9	--	3.1
Total	11.6	11.2	6.8	2.9	32.4

Source: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, Volume II (Paris, OECD, 1979).

[a] Rows may not sum exactly due to rounding.

[b] Includes primarily residential, agriculture, public service, and commercial sectors.

[c] Includes nonenergy uses and unallocated final consumption.

Table 3-11. India: Changes in Final Energy Consumption, 1967-75

(million metric tons of oil equivalent)[a]

Sector / Fuels	Industry	Transportation	Household and related sectors[b]	Other[c]	Total
Coal	12.4	-1.2	2.1	-5.2	8.1
Oil	0.4	4.0	2.5	0.8	7.7
Gas	0.4	--	--	--	0.3
Electricity	3.2	0.1	1.0	-1.5	2.8
Noncommercial	0.9	--	4.8	--	5.7
Total	17.3	2.9	10.4	-5.9	24.6

Source: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, Volume II (Paris, OECD, 1979).

[a]Rows may not sum exactly due to rounding.

[b]Includes primarily residential, agriculture, public service, and commercial sectors.

[c]Includes non-energy uses and unallocated final consumption.

Chapter 4

GOVERNMENT POLICIES AND THE COMPOSITION OF ENERGY USE

Introduction

In this chapter we will briefly discuss the effects of government policies upon the composition of energy use in developing countries. A wide range of policies affect the composition of energy use. Policies vary widely among countries, change rapidly, and are inconsistently applied, making it difficult to obtain information on or to generalize about their effects. However, we may outline those policies which are most significant for the composition of energy use, while providing examples from several countries.

Policies affecting energy are of two kinds: those specifically directed towards energy production or consumption, and those dealing with the overall management of the economy or of constituent sectors of the economy which may have major implications for energy. Policies of the first sort are, by definition, motivated by concern with energy problems and are expected to have planned effects on the problem. Policies of the second sort, however, are motivated by wider concerns, and their effects on energy may not be foreseen. Examples of this second type of policy are transport sector regulations and fiscal policies. The two types of policies may reinforce or may offset each other.

With regard to policies affecting the overall management of the economy, in the two decades preceding the 1973-74 oil price rise, most countries followed macroeconomic policies associated with a rapid increase in commercial energy consumption. The main thrust of these policies was to promote rapid economic growth through industrial development and the modernization of agriculture. This led inevitably to the rapid increases in the use of commercial fuels referred to repeatedly in this study. In particular it led to increases in the use of oil due to its cheapness, convenience and importance in modern industrial technologies. The increase in urban population which was associated with development also led to rising consumption of commercial fuels in the household sector. Faced with this rapid increase in consumption of commercial fuels, a variety of policies were adopted which affected the composition of energy use.

Production Policies

In general, the policies of developing countries with regard to energy production have had the goal of providing adequate and reasonably secure energy at reasonable costs to both households and other users of energy. Policies to pursue this goal have varied according to countries' resource bases.

For countries poor in energy resources, energy had to be imported. The extent to which government policies affected the composition of energy imports is uncertain. As has been discussed in the previous two chapters, prior to 1970, economic forces shifted steadily to favor the importation of oil over coal, as both oil export prices and oil transportation costs fell relative to those of coal, and as new technological change favored the use of oil. However, it is unclear whether policies such as allocation of foreign exchange were employed to further favor the use of oil over coal.

Supply policies for those developing countries (excluding the major oil exporters) with domestic fuel resources were more complex, involving, as the international price of petroleum declined, decisions to subsidize or abandon development of domestic resources.

Exploration and development of indigenous energy resources can be encouraged in a number of ways--by tax privileges, by direct support to exploration, leasing arrangements and so on. In addition, existing indigenous production can be protected against the incursion of cheaper imported fuels by protective devices. These include subsidies to domestic industries, import restrictions and duties, and selective taxation of competing forms of energy. It is beyond the scope of this study to investigate the whole range of development and protective policy measures applied by developing countries, but in general governments appeared pleased to take advantage of supplies of cheaper imported fuel prior to 1970.

However, following the oil price rises of the early 1970s, governments adopted a wide-ranging variety of measures to reduce imports and encourage domestic supply development.

An example of government subsidization of coal production is provided by Korea, where coal accounted for 41 percent of total commercial energy requirements in 1975. Over half of this coal was used in the residential sector, for heating and cooking.[55] Korean government policy has been aimed at providing cheap fuel for residential uses. To ensure adequate production levels, the government provided incentives in the form of subsidies to consumers and direct financial assistance to mines. Since the rise in oil prices, the government has taken steps to increase coal output by making grants of up to 70 percent of the cost of developing a mine and low interest loans for an additional 15 percent.[56] These funds are provided partly by a tax levied on Bunker C fuel oil. The success of this policy is reflected in a sharp rise in coal production from 12.4 million tons in 1972 to 17.6 million tons in 1975.[57]

In the short run, price changes, taxes, and subsidies may have little effect on energy use. The more costly and fuel specific is energy-using equipment, the less price elastic fuel use will be in the short run. An alternative to pricing policies is direct physical allocation, such as was used in the Indian industrial sector after 1973 to restrict oil use and encourage replacement of oil by coal. Initially, oil users were given quotas equal to their 1973 consumption; then cuts were imposed based on a judgment regarding substitution possibilities. A firm could get its allocation increased if it proved that it needed more oil for export production, for import substitution, or to cater to defense demand. New firms had to be recommended by one of the designated sponsoring authorities before their application for an allocation could be considered. Large savings were achieved immediately by switching a

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55. International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979) p. 372.

56. Parvez Hasan and D. C. Rao, Korea: Policy Issues for Long-Term Development (published for the World Bank by Johns Hopkins University Press, Baltimore, MD, 1979) p. 288.

57. United Nations Statistical Office, World Energy Supplies: 1972-1976, Statistical Papers Series J, no. 21 (New York, UN, 1978) p. 24.

small number of power stations from oil to coal.[58]

A fuel-efficiency advisory service was set up to help firms save energy. Calculations by Desai indicate that fuel oil use in major Indian industries in 1977 was reduced from what it would have been had oil use/output ratios remained the same as in 1973 by an amount equal to 30 percent of 1973 consumption.[59] After 1976, however, difficulties in obtaining supplies of high-quality steam coal, and the exhaustion of low cost substitution possibilites impeded further replacement of oil with coal.

Similar measures were used in Brazil to restrain oil consumption after 1973. Crude oil imports were frozen, quotas were introduced, and certain industrial operations were obliged to switch from oil to coal. As in India, these included the cement industry, which was up to 1973 one of the larger industrial consumers of fuel oil.[60]

In developing countries, supplies of electricity increased more rapidly than supplies of other forms of energy. Government policies were generally to encourage the rapid expansion of the electricity sector both by financial assistance to construction of generating facilities and by financing operating deficits stemming from subsidized tariffs. In developing countries typically a very large proportion of this electricity is generated from hydroelectric capacity rather than imported fossil fuels. There has been particular interest in recent years in pressing ahead with development of hydro resources, and in several countries--Korea, India, Brazil--with nuclear generation.[61] So great is the interest in accelerated development of electricity that several countries plan to have a larger share of electricity in total energy supplies than most of the industrialized countries.

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58. Ashok V. Desai, "Interfuel Substitution in the Indian Economy," Discussion Paper from the Center for Energy Policy Research, D73-B (Washington, D.C., Resources for the Future, July 1981) p. 10.

59. Desai, "Interfuel Substitution," p. 10.

60. Desai, "Interfuel Substitution," p. 12.

61. Joy Dunkerley, John E. Jankowski, Jr., Malcolm Gillis, R.K. Pachauri, Pierre Ehrlich et al., and Robert Kahn, "Assessment of Energy Demand Projections for Selected Developing Countries." Draft prepared for Office of Long-Range Assessment and Research, U.S. Department of State (Washington, D.C., Resources for the Future, August 1980).

An interesting example of government-encouraged interfuel substitution following the 1973-74 rise in oil prices is the alcohol program in Brazil. Here anhydrous ethanol made from sugarcane is mixed with gasoline in a proportion of one to four to make an automotive fuel which can be burned in standard model cars. Further plans envisage the use of 100 percent ethanol in specially designed cars, and the substitution of ethanol for both diesel fuel and feedstock for the petrochemical industry. The alcohol program receives major governmental support. Furthermore, incentives are to be offered for the purchase of the new 100 percent ethanol driven cars.[62]

As discussed in chapter 3, governments and international organizations have undertaken a variety of efforts to increase fuelwood production, such as village woodlots. In most countries, the scale of these efforts remains small compared to the magnitude of fuelwood consumption and deforestation problems (an exception is Korea, where a fuelwood plantation program had covered more than half a million hectares by 1975).[63] Difficulties with communal fuelwood production programs suggest that in many areas, more attention should be focused on encouraging private fuelwood production. Measures could include the establishment of nurseries, research into and demonstration of high-yielding varieties and techniques of agroforestry, improved transportation facilities to allow the utilization of wood formerly wasted due to high transport costs, and general forestry education and propaganda. In addition, governments should concentrate on reducing institutional causes of the fuelwood crisis. New fuelwood plantations will not be adequate if other areas continue to be deforested at a faster rate.

Demand Policies

One way in which government policies affect the structure of energy demand is by affecting the structure of demand for fuel outputs. One example may be

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62. Kenneth Paul Erickson, "Brazil" in Kenneth J. Stunkel, ed., National Energy Profiles (New York, Praeger, 1981).

63. United Nations Food and Agriculture Organization, "Village Fuelwood Plantations in Korea," FAO Forestry Paper 17, Supplement 1, Case Study no. 2 (Rome, FAO, 1979) p. 1.

found in the transportation sector, where policies favoring road over rail transport, and within rail transport, diesel locomotion over steam, have resulted in a sharply increasing share of petroleum products in transportation energy. For many countries this aspect of interfuel substitution had already been completed in the years before sectoral data were available to document it. But India, where the change to diesel locomotion took place later than in other countries, provides an interesting example of the importance of sectoral policies on the types of fuels used. A steam engine factory was built in 1950, as a first step in the post-independence industrialization. Although the use of steam engines was uneconomical for most purposes by the 1960's, steam engines were produced until 1971 in order to make use of production capacity and labor.[64]

In Brazil, the rapid growth of the automobile industry sponsored by the government and facilitated by subsidized gasoline in the 50's and 60's contributed to the rising share of petroleum products in total consumption.

In addition to policies affecting energy use indirectly by affecting the structure of final demand, governments affect demand directly through pricing policies such as price controls, subsidies, and taxes. Governments use price controls or subsidies to encourage consumption of a fuel or to benefit consumers of the fuel. Taxes are used to raise revenue as well as to discourage consumption. There is great variation in the energy pricing policies of developing countries. In addition, since subsidies and taxes may be introduced at various levels of production of energy, as well as in sales to consumers, it is difficult to determine the exact extent to which various fuels are subsidized or taxed. However, we may provide examples of pricing policies which affect the composition of energy use.

Some fuels may be abundant locally but difficult to export, such as hydroelectricity or natural gas. These fuels are usually priced attractively to encourage total use.

A widespread policy followed by developing countries is to keep prices of fuels used primarily in the residential sector--kerosine, coal products, and electricity used by rural consumers--low through subsidies. This is an

64. Desai, "Interfuel Substitution," p. 25.

understandable concern as in the lower income groups virtually all income is spent on food and the energy necessary to prepare it. Governments face similar pressures to keep down energy prices as they do to keep down prices of basic foodstuffs.

In Korea prices of coal used by domestic consumers are subsidized.[65] In most countries electricity tariffs paid by small consumers, especially those in rural areas, are also frequently subsidized. In parts of rural Central America, for example, subsidies amount to about 30 percent of total costs of electricity.[66]

Table 4-1 gives prices of household kerosine and gasoline in a number of countries, including oil exporters and oil importers for 1973 and 1977. The wide variation in prices illustrates the diversity among countries in pricing policies. In a few countries, kerosine prices were actually below the export price of Saudi Arabian crude oil (a rough measure of the world price), indicating significant subsidization. If costs of refining, transportation, and retailing are included, the extent of subsidization would appear much greater.

Subsidies are expensive policies for aiding the poor, since they also benefit other groups. Thus in Indonesia, survey data for 1976 indicated that the poorest 40 percent of the population used only 20 percent of the kerosine. Specifically the evidence suggested that for every one rupiah of kerosine subsidy benefitting the very poor, four rupiahs of that subsidy benefit the relatively well-off. Furthermore, since the 1973-74 rise in oil prices kerosine subsidies have led in several cases to sharply rising budgetary costs. In Indonesia, for example, subsidies on oil products amount to 9 percent of total tax revenue, almost $10 per barrel of domestic consumption of oil products.[67]

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65. Hasan and Rao, Korea: Policy Issues, p. 288.

66. World Bank, "Rural Electrification," A World Bank Paper (Washington, D.C., World Bank, October 1975) p. 26.

67. Dunkerley and coauthors, "Assessment of Energy Demand Projections," p. 255.

Table 4-1. Retail Prices of Kerosine and Regular Gasoline, Selected Developing Countries, 1973 and 1977[a]

	1973		Ratio of kerosine to	1977		Ratio of kerosine to
	Kerosine	Gasoline	gasoline	Kerosine	Gasoline	gasoline
Argentina	34.0	60.4	.56	45.9	82.6	.56
Bolivia	6.0*	17.0	.35	5.6*	27.8*	.20
Brazil	27.2	29.2	.93	83.2	151.2	.55
Burma	20.8	43.3	.48	29.2*	40.8	.72
Chile	37.8	56.7	.67	52.9	90.7	.58
Colombia	12.6	14.3	.88	26.1*	27.4*	.95
El Salvador	18.0	52.0	.35	64.0	97.6	.66
Ethiopia	68.8	89.5	.77	82.0	121.3	.68
Ghana	29.2	54.2	.54	72.5	101.5	.71
India	30.7	71.2	.43	54.6	142.4	.38
Jamaica	14.7	37.6	.39	32.0	171.7	.19
Kenya	33.3	59.0	.56	69.0	125.0	.55
Mexico	10.3	24.2	.43	9.0*	46.0	.20
Morocco	43.7	89.3	.49	65.0	160.0	.41
Pakistan	16.7	50.8	.33	31.0	108.0	.29
Panama	22.0	46.8	.47	50.1	100.0	.50
Paraguay	42.0	57.0	.74	78.0	150.0	.52
Peru	4.0*	21.0	.19	12.0*	93.0	.13
Philippines	16.0	18.0	.89	57.2	84.8	.67
Portugal	30.4	84.6	.36	45.4	177.6	.26
Sri Lanka	17.5	71.7	.24	40.0	146.7	.27
Thailand	36.0	39.0	.92	50.0	73.3	.68
Tunisia	65.9	161.0	.41	36.6	155.5	.24
Turkey	36.2	41.7	.87	52.4	58.0	.90
Uruguay	30.0	85.0	.35	84.0	157.0	.54

Source: Darrel G. Fallen-Bailey and T.A. Byer, Energy Options and Policy Issues in Developing Countries, World Bank Staff Working Paper no. 350 (Washington, D.C., World Bank, August 1970) p. 102.

*Price is below the realized price for Saudi Arabian crude oil of 6.4¢ in 1973 or 29.5¢ in 1977. World Bank, Commodity Trade and Price Trends, Report No. EC-166/79 (Washington, D.C., World Bank, August 1979) p. 94.

[a]Prices include taxes, and are in U.S. cents per gallon. Data are for capital cities, except for Brazil where data are for Rio de Janeiro.

While kerosine is typically subsidized or taxed at a very low rate, industrial fuel oil is usually taxed at a higher rate, and gasoline is taxed still higher. The effects of these differences in taxes may be seen in table 4-1 in the ratio of the price of kerosine to the price of gasoline. For every country in the table, the retail price of kerosine was lower than the retail price of regular gasoline. The 1977 kerosine prices were as low as 20 percent of gasoline prices in countries such as Bolivia, Jamaica, Mexico, and Peru.

The role of taxes in bringing about this price differential between kerosine and gasoline may be seen in table 4-2. In all but six of the countries in the table, taxes on kerosine were less than 30 percent of taxes on gasoline in 1977. A limitation on the effectiveness of varying tax and subsidy rates to bring about wide price spreads between oil products is that they may cause a distortion of demand, resulting in substitution between fuels by consumers. For example, kerosine may be mixed with gasoline in modified car engines, and kerosine can also be mixed with diesel fuel.[68]

High taxes on oil products serve to encourage the use of other fuels. According to Desai, "The chief reason for the slower decline in the use of solid fuels in India was to be found in the government's energy pricing and tax policies."[69] Prior to 1973, the position of coal was retained through the imposition of taxes on oil products--300 percent on gasoline and diesel fuel and about 110 percent on kerosine and furnace oil. Subsequently, as discussed above, physical allocation also helped to limit oil consumption in favor of coal.

Since 1973, taxes on petroleum products have been raised in some countries but lowered in others, as shown in table 5-2. In general, retail prices of gasoline were allowed to rise more rapidly than those of kerosine. Thus for sixteen of the twenty-five countries in table 5-1, the ratio of the price of kerosine to the price of gasoline fell between 1973 and 1977. One type of de facto subsidy was common in those countries which produce as well as import oil. The Indian government, for example, in an effort to protect refiners from

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68. An excellent discussion of energy pricing policies in India and their effects on the composition of energy use may be found in Desai, "Interfuel Substitution," pp. 52-58.

69. Desai, "Interfuel Substitution," p. 6.

Table 4-2. Taxes on Kerosine and Regular Gasoline, Selected Developing Countries, 1973 and 1977[a]

	1973			1977		
	Kerosine	Gasoline	Ratio of kerosine to gasoline	Kerosine	Gasoline	Ratio of kerosine to gasoline
Argentina	14.2	44.7	.32	21.0	65.2	.32
Bolivia	0.0	4.0	.00	0.6	2.8	.21
Brazil	3.9	9.7	.40	7.6	37.8	.20
Burma	0.8	24.2	.03	1.7	2.5	.68
Chile	3.1	23.6	.13	5.3	37.8	.14
Colombia	0.2	4.2	.05	0.1	6.2	.02
El Salvador	0.0	25.7	.00	0.1	54.1	.00
Ethiopia	34.9	43.8	.80	12.9	22.7	.57
Ghana	1.2	28.8	.04	13.1	25.1	.52
India	12.2	49.3	.25	18.9	92.8	.20
Jamaica	0.0	13.6	.00	0.0	110.7	.00
Kenya	7.2	31.3	.23	6.0	55.0	.11
Mexico	1.6	4.5	.36	0.0	15.0	.00
Morocco	20.0	53.0	.38	24.9	103.5	.24
Pakistan	5.0	37.5	.13	23.0	61.0	.38
Panama	15.3	13.7	1.12	1.7	43.2	.04
Paraguay	9.0	20.0	.45	7.0	24.0	.29
Peru	0.2	8.0	.03	0.6	31.0	.02
Philippines	2.1	5.2	.40	3.6	25.5	.14
Portugal	5.7	59.7	.10	22.9	118.8	.19
Sri Lanka	5.0	31.0	.16	3.2	26.4	.12
Thailand	7.5	16.1	.47	6.2	26.8	.23
Tunisia	18.8	73.7	.26	27.4	238.1	.12
Turkey	17.2	25.3	.68	16.6	22.9	.72
Uruguay	4.0	42.0	.10	11.0	64.0	.17

Source: Darrell G. Fallen-Bailey and T.A. Byer, Energy Options and Policy Issues in Developing Countries, World Bank Staff Working Paper No. 350 (Washington, D.C., World Bank, August 1979) p. 103.

[a]Taxes are in U.S. cents per gallon. Data are for capital cities, except for Brazil where data are for Rio de Janeiro.

the full increase in international oil prices provided supplies to refineries at the 1973 import parity prices until 1976.[70] This represents a massive cross-subsidization of imported oil by local crude, and substantially weakens oil conservation policies.

The pricing picture is therefore extremely complex and frequently contradictory, reflecting a conflict between the desire to protect poor populations against sharp price increases and the inevitability of allowing prices to rise. Superimposed on this picture of rising energy prices is a sharp rise in prices of all goods such that the real rise in prices of many energy products has been relatively small.

Conclusion

What did governments do, if anything, to promote more advantageous supply or consumption conditions of one fuel rather than another? On the side of supply we have seen that all countries tried to promote the particularly rapid development of electricity. Prior to 1973, considerations of cost and convenience favored imported oil over imports of other fuels or development of more expensive domestic resources. Subject to foreign exchange constraints, official policy did not impede this trend.

In countries which possessed major coal resources, government support in forms ranging from direct subsidies to production to preferential tax treatment was accorded. As in industrial countries, quite drastic measures were required to retain a major role for coal in the face of increasing competition from oil. After 1973 physical allocation of fuels became more important in some markets, in particular coal and oil.

The major feature of the demand side is the multiplicity of subsidies, such as kerosine and electricity consumed by the poor or in rural areas, coal used in industry, or diesel fuel used in transportation. It is consequently difficult to judge whether any fuel received systematically preferential treatment. Since 1973, however, there has been some move to increase kerosine prices, so that the position of kerosine vis-a-vis other residential fuels has deteriorated.

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70. Desai, "Interfuel Substitution," p. 52.

Chapter 5

CONCLUSIONS: IMPLICATIONS FOR THE FUTURE

There are two primary trends in the composition of energy use over time. The first is the declining share of noncommercial fuels in total energy use. As data are not available it is not possible to document this trend for groups of developing countries over long periods. But data available for selected developing countries testify to this major development. The other major trend in the composition of energy supplies over time lies within the commercial fuel sector. In the developing countries, as in the industrial countries, the share of coal in total energy use has fallen, and the share of oil, electricity, and in some cases gas, has risen. These two developments in the composition of fuel supplies over time are noticeable on a more disaggregated basis in all those sectors in which changes in the composition of energy supplies appear feasible--industry, electricity generation and household uses.

In the industrial sector the share of industrial energy provided by coal and noncommercial fuels has fallen, and the share of electricity, and in most cases petroleum products, has risen. For many countries petroleum products and electricity now account for virtually all of the energy consumed in this sector. In electricity generation hydroelectricity dominates in developing countries but even here there have been some changes in the composition of generating capacity, in particular a sharp rise in the share of oil-fired capacity. In the household sector, the share of noncommercial fuels has fallen as the share of both petroleum products and electricity rose.

What caused these consistently observed trends in the composition of energy use? There appear to be two main causes--the rapid expansion of "modern" activities requiring commercial fuels and declining real oil prices prior to 1970. In the industrial sector, for example, the decline in noncommercial fuels appear to be due primarily to the rapid growth in modern industrial activities. The substitution of oil and electricity for coal was due to declining relative prices, reflected also in current technologies. Declining oil prices coupled with lower capital costs compared with other types of generation also appear to be largely responsible for the increasing share of oil-fired electricity generation.

In the household sector rising real income led to a rising share of commercial fuels because of their greater convenience, and by rapid growth in demand for energy services (such as electric appliances) which could only be met by commercial fuels. This tendency was reinforced by the rapid growth in urban population without access to traditional fuels, and by declining real prices of frequently subsidized kerosine.

In these sectors, changes in the composition of the fuels used is feasible as the uses to which they are put can be met by several types of fuels. There are other sectors, however, which are tied to specific fuels, in particular oil. These are the transportation sector and the nonenergy sector (the use of oil as feedstock in petrochemicals). The expansion of these sectors automatically led to increasing reliance on petroleum products in total fuel supplies. In the cases of India and Brazil, for example, increases in oil consumption in the transportation sector accounted for 52 percent and 46 percent, respectively, of the total rise in oil consumption between 1967 and 1975.

The analysis of historical trends indicates a wide measure of shared experience in developing countries. But inter-country comparison points to still considerable differences in the composition of energy use among countries. While most countries now depend heavily on oil, in many countries exceptional domestic resource endowments have meant a major role for other fuels--examples include coal in India, gas in Nigeria and Mexico, and noncommercial fuels even in such highly developed countries as Brazil. The easy availability of oil on a worldwide basis diminished the importance of domestic resource endowment, but it continues to be a decisive factor in some circumstances.

Many of the developments described above occurred in response to changing economic conditions, in particular the fall in the real price of oil. But government intervention also played a major role, in some cases reinforcing already existing trends and in others trying to withstand them. On the side of supply most countries tried to promote rapid development of electricity. In countries which possessed major coal resources, quite drastic measures were sometimes used to retain a major role for coal in the face of increasing competition from oil. This was frequently given in the form of direct subsidies to production and preferential tax treatment. After 1973, physical allocation of fuels, both coal and oil, became more important in some markets.

The major feature of government intervention on the demand side was the multiplicity of subsidies on those fuels consumed by the poor--kerosine, coal, and rural electric consumption. Fuel oil and diesel often benefitted from low tax rates, while high taxes were levied on gasoline. Since 1973, a number of countries have raised prices for petroleum products by reducing subsidies or raising taxes in an effort to encourage conservation. These moves have frequently met with strong opposition, especially when increases in prices of mass consumption goods such as kerosine and mass consumption services such as bus fares have resulted.

What are the possibilities for future changes in the composition of energy use away from imported oil? This will depend on the relative prices of the different sources of energy, the development of energy supplies, the evolution of demand for energy and government policies. A detailed analysis of these topics is beyond the scope of this paper but a short summary of the resource position of the oil-importing developing world can give a preliminary idea of the problems and opportunities.

Countries vary widely in their endowments of proven fossil fuel reserves as well as hydroelectric potential. Those countries most dependent upon oil imports tend to be the least well-endowed with fossil fuel resources, on a per capita basis. However, past exploration for oil, natural gas and coal has been much less intensive in the developing than in the developed countries. New discoveries may be very significant in terms of reducing energy dependence in the countries in which they take place.

But more intensive exploration activities are hampered by a number of factors. High costs of exploration in remote areas, together with a shortage of risk capital and numerous difficulties in dealing with foreign oil companies, have slowed the pace of exploration for oil. The same problems affect exploration for natural gas, along with the greater difficulties of transporting and marketing natural gas. Known coal resources are distributed more extensively than those of oil or gas. However, in a number of countries, coal resources are not yet economically or technically recoverable. In addition, high infrastructure costs for mining, transportation, and handling have slowed the development of coal.

Expansion of hydroelectric power is limited by high construction costs and insufficient demand in many countries. Nuclear power plays only a minor role in LDC power generation. The future for nuclear power, even for those few countries with a large enough grid to accommodate the current size of nuclear plants, is plagued with reliability and safety problems.

For many countries, including those with the highest rates of import dependence, fuelwood availability is declining. As a renewable resource, as opposed to a nonrenewable resource, it is in theory possible to increase fuelwood supplies on a predictable and sustainable basis. However, this task is complicated by competition with agriculture for scarce land resources, population pressures, and the common property nature of areas where fuelwood is gathered. To reverse the trend of increasing scarcity will require major investments and organizational changes.

At present, fuelwood and the other biomass resources (animal and crop wastes) are largely restricted to rural uses in primitive applications. If biomass fuels are to be substituted for commercial fuels on a large scale, conversion technologies must be developed and facilities constructed and major organizational changes must take place in agriculture and forestry.

The picture on the resource side then is a mixed one. Even where it is possible to be optimistic with regard to resources of conventional and renewable fuels, problems are posed by the costs of developing new supplies, obtaining investment funds and the organizational changes required.

Supply prospects are only one side of the picture. The other is the types of demands for energy which are likely to develop. In the pre-1973 days a reasonable prognostication for energy demand in developing countries might have been that it would follow the patterns established by industrial countries. The radical change in energy prices has cast doubt on such assumptions though it is not clear how energy demand will develop under these new circumstances. This is a topic which requires further research as it concerns not only the amount of energy to be consumed but also the forms in which it will be required.

Despite major uncertainties about future trends in energy consumption, some features rooted strongly in past experience seem likely to continue. The first is the continued decline in the share of noncommercial fuels used in their present form in total energy supplies. As urban populations and modern commercial activities continue to grow more rapidly than rural populations and traditional rural-based activities, the proportion of commercial fuels in the total will also continue to grow. This trend could be slowed by using biomass resources in different ways--more efficiently in traditional uses such as cooking and by conversion to modern fuels (liquids, solids and electricity).

With regard to the composition of commercial fuel supplies, of primary concern is the share of petroleum products in the total. A first question is what is likely to happen to those sectors which are inherently oil-using--transportation and petrochemicals. Again these are questions which merit major research efforts, but certain *a priori* assessments can be made. The transportation sector is likely to grow as development proceeds. Even at relatively low levels of industrialization, developing countries may have a higher freight transportation intensity (that is, the number of freight miles traveled relative to GDP) than some industrial countries because of the predominance of one major center in the economy. As regional development proceeds, however, freight intensity may fall. On the other hand, as incomes rise, demand for passenger transport and particularly private passenger transport will rise. The use of liquid fuels as feedstock for petrochemicals will depend on development strategies and also on the cost advantages of importing rather than domestic manufacture.

In the other sectors--electricity, industry and households--there are greater possibilities for substituting other fuels for liquids. The electricity sector has the greatest potential for substitution, using coal, gas, hydroelectric power, and nuclear power. While aided by rapid rates of growth in the electricity sector, the long lead times in developing electricity generating facilities means that it will still take some years before this changing composition becomes effective. In the meantime there are some possibilities for converting existing oil-fired facilities to gas or to coal. The conversion to gas is technically straightforward but is dependent on the local availability of gas at reasonable prices. The conversion to coal is more difficult, depending on whether coal-handling facilities are already in place. This is most likely to happen in countries which already have a coal industry.

The rapidity of growth in the industrial sector also offers possibilities of reducing the role of liquid fuels in the future as new additions to the capital stock using other fuels are made. In the household sector, the wide variety of fuels used indicates the possibility of reducing the role of petroleum products. However, the key role of (frequently subsidized) kerosine may prove a major obstacle to achieving this reduction.

Several countries have published energy plans giving some indication of their plans for the composition of fuel supplies in the future. One common feature is an anticipated sharp increase in the share of electricity. Indeed, in some cases the anticipated size of the electricity sector by the end of the century raises questions about how the electricity is to be used. As might be expected most countries plan on a reduction in the share of petroleum products.[71] To a large extent, the feasibility of diminishing oil's share in total energy supplies will depend on the structure of prices. In 1970 export prices of oil were less than half those of coal. The lower price of oil was reinforced by qualities such as cleanliness, convenience, and ease of handling and transport. By 1978 export prices of oil were slightly higher than those of coal, and there are major doubts about future availability. On the other hand, oil still remains one of the most convenient and flexible forms of fuel. It is not clear how great a margin between fuel prices is needed to induce a widespread move to coal or alternative forms of fuel.

These considerations point to a continued, probably intensified, role for government in energy policy. The rationale for this role, supplementing whatever reaction is taken by consumers following the sharp rise in oil prices, lies in the difference between private and social costs of using energy and the need to accelerate the time frame in which adjustments are made. As we have seen, governments played a major role in energy policy in the past, so that this is not a new initiative. However, past interventions were not primarily motivated by concern with the composition of fuel use. Thus, the main concern of governments in the 1960s and early 1970s was the provision of cheap sources of supply tempered where necessary by the need--bolstered by accompanying

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71. Korea is a noteworthy exception. In the Long-Term Prospect for Economic and Social Development 1977-91 (Korea Development Institute, Seoul, Korea, 1978), the share of oil is planned to rise. This plan was, however, drafted before the recent (1979) rise in oil prices.

political pressures--to retain some place for a major domestic industry. Governments subsidized many forms of energy, keeping prices low both in order to relieve poverty as well as to promote modernization.

Government policies in the future are likely to be rather different, with a higher priority placed on substituting other fuels for oil. The experience surveyed here shows that it is possible, as witnessed in several countries which rely heavily on other fuels. However, interfuel substitution may not be easy to achieve. For one thing, relative costs of using the different fuels may still favor oil in many end uses. Secondly, governments do not start with a clean slate. It may not be possible, especially in a relatively short period, to dismantle systems of subsidies and differential taxation affecting oil products. These systems were instituted largely in response to political pressures, which will oppose radical or sudden changes. More coordinated efforts will be needed to change patterns of fuel use in the future. Efforts to promote interfuel substitution will require an integrated approach with regard to pricing, energy supply, and the major end-use sectors.

Appendix A

ENERGY CONSUMPTION BY FUEL AND BY END USE

Table A-1. Shares of Total Oil Consumption, by Sector, 1975[a]

(percent)

	Generation of electricity	Industry	Transportation	Other final sectors[b]	Other primary sectors[c] and nonenergy uses	Unallocated[d]
India	8.6	14.0	37.7	25.6	14.1	0.0
Kenya	7.0	16.0	55.8	20.0	1.1	0.0
Egypt	12.4	0.0[e]	19.7[e]	17.2[e]	1.8[e]	49.0
Indonesia	4.0	1.4[e]	27.2	29.3[e]	1.9[e]	36.2
Nigeria	0.0	20.0	46.2	8.5[e]	4.6[e]	20.7
Thailand	14.6	18.9	40.9	20.9	4.7	0.0
Korea	26.5	0.2[e]	5.2[e]	3.8[e]	12.5[e]	51.8
Colombia	7.8	0.0[e]	49.7	11.6[e]	5.8[e]	25.0
Mexico	15.8	25.8	41.9	11.1	5.4	0.0
Turkey	10.8	20.0	38.6	26.6	4.0	0.0
Brazil	2.5	29.3	46.5	10.7	8.6	2.4
Portugal	14.0	28.0	38.2	11.8	8.0	0.0
Italy	21.7	29.9	21.8	25.8	0.8	0.0
Japan	24.4	31.6	20.1	18.6	5.2	0.0
USA	11.1	11.3	58.9	17.9	0.9	0.0
Germany	3.9	24.0	26.0	36.0	10.1	0.0

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December, 1978, vol. II (Paris, OECD, 1979); International Energy Agency, Energy Balances of OECD Countries, 1974-1978 (Paris, OECD, 1980).

[a] Total oil consumption includes net imports, net changes in marine bunkers and stock changes, and indigenous refinery production.

[b] Primarily agriculture, commercial use, public service, and residential.

[c] Primarily gas manufacture, own use by energy sector, and statistical differences.

[d] Final use not allocated by sector.

[e] Share may actually be much larger, due to large share of final energy use unallocated by sector.

Table A-2. Shares of Total Coal Consumption, by Sector, 1975[a]

(percent)

	Generation of electricity	Industry	Transportation	Other final sectors[b]	Other Primary sectors[c] and nonenergy uses	Unallocated[d]
India	26.2	56.0	16.0	3.8	0.0	-2.1
Kenya	0.0	7.1	92.9	0.0	0.0	0.0
Egypt	2.8	96.8	0.0	0.0	0.3	0.0
Indonesia	0.0	39.1	24.2	0.0	28.9	7.8
Nigeria	0.0	100.0	0.0	0.0	0.0	0.0
Thailand	91.9	8.1	0.0	0.0	0.0	0.0
Korea	4.4	13.7	0.2	72.9	0.0	8.7
Colombia	7.7	15.1[e]	0.0[e]	0.0[e]	0.1[e]	77.1
Mexico	1.9	98.1	0.0	0.0	0.0	0.0
Turkey	10.9	7.8	3.6	70.0	7.6	0.0
Brazil	27.7	61.5	0.4	0.0	0.0	10.5
Portugal	32.6	47.8	4.3	2.2	13.0	0.0
Italy	18.7	49.2	0.8	10.0	21.3	0.0
Japan	21.4	52.9	0.1	7.0	18.7	0.0
USA	72.7	24.2	0.0	1.5	1.6	0.0
Germany	58.8	21.1	0.4	10.1	9.6	0.0

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December, 1978, vol. II (Paris, OECD, 1979); International Energy Agency, Energy Balances of OECD Countries, 1974-1978 (Paris, OECD, 1980).

[a]Total coal consumption includes indigenous production and net imports and changes in stock. The energy content of "secondary solid fuels" was converted to that of "primary solid fuels" based upon the efficiency of production of secondary solid fuels from primary solid fuels.

[b]Primarily agriculture, commercial use, public service, and residential.

[c]Primarily gas manufacture, own use of energy sector, and statistical differences.

[d]Final use not allocated by sector.

[e]Share may be much larger, due to large share of final energy use unallocated by sector.

Table A-3. Shares of Total Gas Consumption, by Sector, 1975[a]

(percent)

	Generation of electricity	Industry	Transportation	Other final sectors[b]	Other Primary sectors[c] and nonenergy uses	Unallocated[d]
India	15.7	48.8	0.0	3.6	31.9	0.0
Kenya[f]	--	--	--	--	--	--
Egypt	0.0	94.0	0.0	6.0	0.0	0.0
Indonesia	0.0	5.9[e]	0.0	24.4[e]	13.8[e]	55.9
Nigeria	43.9	56.1	0.0	0.0	0.0	0.0
Thailand[f]	--	--	--	--	--	--
Korea[f]	--	--	--	--	--	--
Colombia	13.9	0.0[e]	0.0	3.0[e]	39.2[e]	43.9
Mexico	11.1	64.6[e]	0.0	2.6[e]	0.0[e]	21.6
Turkey	0.0	0.0	0.0	80.0	20.0	0.0
Brazil	29.6	53.6	0.0	16.7	-0.8	0.1
Portugal	0.0	0.0	0.0	80.0	20.0	0.0
Italy	9.3	54.7	1.4	32.5	2.1	0.0
Japan	34.0	16.5	0.0	44.0	5.5	0.0
USA	15.9	31.1	0.0	37.6	15.3	0.0
Germany	30.7	43.6	0.0	23.2	2.5	0.0

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December, 1978, vol. II (Paris, OECD, 1979); International Energy Agency, Energy Balances of OECD Countries, 1974-1978 (Paris, OECD, 1980).

[a]Total gas production includes indigenous production (including production from coal and oil), not imports and changes in stocks.

[b]Primarily agriculture, commercial use, public service, and residential.

[c]Primarily own use by energy sector and statistical differences.

[d]Final use not allocated by sector.

[e]Share may actually be much larger, due to large share of final energy use unallocated by sector.

[f]These countries consume no gas.

Table A-4. Shares of Total Electricity Consumption, by Sector, 1975[a]

(percent)

	Industry	Transportation	Other final sectors[b]	Other primary sectors[c] and nonenergy uses	Unallocated[d]
India	48.8	2.4	23.9	8.7	16.3
Kenya	37.8	0.0	50.0	0.0	12.2
Egypt	49.2	0.0	33.5	0.0	17.3
Indonesia	30.5	0.0	68.7	0.0	0.8
Nigeria	49.8	0.0	34.8	0.0	15.4
Thailand	64.0	1.2	18.7	0.0	16.1
Korea	68.8	1.3	15.8	2.9	11.3
Colombia	41.3	0.0	51.6	0.1	7.0
Mexico	56.5	0.0	37.0	0.0	6.5
Turkey	56.3	0.7	21.5	20.7	0.0
Brazil	41.0	0.0	47.1	0.0	11.9
Portugal	47.9	2.1	35.1	14.9	0.0
Italy	52.7	3.3	28.3	15.7	0.0
Japan	58.3	2.9	27.2	11.7	0.0
USA	29.5	0.2	51.2	19.2	0.0
Germany	41.4	2.9	40.5	15.2	0.0

Sources: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977, Proceedings of Workshop on Energy Data of Developing Countries, December, 1978, vol. II (Paris, OECD, 1970); International Energy Agency, Energy Balances of OECD Countries, 1974-1978 (Paris, OECD, 1980).

[a]Total electricity consumption includes domestic production and net imports.

[b]Primarily agriculture, commercial use, public service, and residential.

[c]Primarily own use by energy sector and statistical difference.

[d]Final use not allocated by sector.

Appendix B

ENERGY DATA: PROBLEMS OF AGGREGATION AND INTERPRETATION

Introduction

A number of problems arise in the collection and interpretation of data relating to energy use. These result from the great diversity of energy sources and the even greater diversity of uses to which energy is put. In order to study energy use, it is necessary to aggregate over different energy sources as well as over different outputs which energy is used to provide. However, the higher the level of aggregation, the more difficult it is to interpret data, or to isolate the effects of the phenomena being studied from those introduced by the method of aggregation.

Aggregation of Different Energy Sources

There is a wide variety of sources of energy used in developing countries, including such diverse forms as human and animal power, firewood, hydroelectric power, oil, natural gas, and coal. Within a given energy source there may be numerous grades, and the same energy source may be used in widely varying applications.

The efficiency of energy use, or the share of total energy released which is actually used in a given economic activity, varies widely from energy source to energy source. For a given economic activity and energy source, energy efficiency depends upon the other inputs which are applied, such as capital and labor, and the technology with which they are applied.

In order to present data for such a wide range of energy sources, it is necessary to aggregate over different energy sources using common units. Any method of aggregation involves assigning energy weights to physical units of different energy sources.

The best method of aggregation will depend upon the use to which the aggregate measure is to be put. Usually the purpose of aggregate energy measures is to indicate either the cost or the contribution to society of energy use.

The most simple way to determine the cost to society of energy use is to aggregate in terms of the prices of energy resources used. However, where prices are controlled or otherwise distorted, they may not reflect the true cost to society of energy use. If an attempt is made to measure the costs of environmental externalities, it becomes even more difficult to measure the costs of energy consumption.

In studying the contribution of energy, the most common method of aggregation is to assign weights in terms of the theroetical or "total" energy content of each energy source. Where fuels are used for similar purposes with relatively similar efficiencies, aggregation of the total energy content of different fuels may provide a useful indication of the energy contribution of different sources. however, the greater the variation in efficiency of energy use among different energy sources, the less meaningful will be aggregate measures or comparisons of total energy content. Total energy content may bear little relationship to the useful contribution of the energy source in production, or to the ways in which different energy sources could be substituted for each other. As a result, aggregation and comparison of total energy contents of widely varying energy sources may be useless or even misleading for economic analysis.

A much more difficult alternative is to assign weights in terms of "useful energy" provided by different energy sources in different uses. Since the efficiency of energy use may vary widely between different energy sources and different uses, calculation of weights is very difficult and must be somewhat arbitrary. In effect, it is almost impossible to determine what share of total energy use for a given fuel is actually converted into useful energy.

This arbitrariness is occasionally used as an argument against attempts to compare or aggregate over different energy sources in terms of useful energy contributions. however, an implicit, if not explicit weighting of total energy content by efficiency is always necessary for such comparisons or aggregations.

Standard procedures for presentation of energy data involve some compromise between assigning energy weights by total energy content and by useful energy content. Data for fuels which are burned are generally presented in terms of total energy content. Other energy sources are generally presented in terms of useful energy content or in terms of the total energy content of fuels which would be burned in providing similar services.

The most common practice for fuels which are burned is to present fuel consumption in terms of the volume or weight of a standard grade of oil or coal providing an equivalent calorific value in combustion. There are numerous difficulties in calculating appropriate conversion coefficients for the wide range of fuels which are used, especially in developing countries. Noncommercial fuels may be burned much less efficiently than commercial fuels. As a result, the share of useful energy provided by noncommercial fuels may be considerably lower than their share in total energy consumption.

For energy sources which produce electricity but do not involve combustion, such as hydroelectricity and nuclear power, one practice is to calculate the volume or weight of the standard grade of coal or oil needed to produce the same amount of electricity. Another is to report directly the calorific value of the electricity generated. The former practice attributes an energy content to hydroelectricity and nuclear power roughly three times that of the calorific value of the electricity generated.

The energy content attributed by the former practice is more comparable to that of oil in terms of its useful energy content, as electric energy may be used much more efficiently than energy in oil which will first be converted to electricity. The adoption of these different conventions explains much of the differences in the two main sources of data on energy use in developing countries--the United Nations and the International Energy Agency.[72]

Even greater difficulties arise in calculating caloric value equivalents for energy sources which neither involve combustion nor produce electricity, such as human and animal power or direct wind energy. Various attempts have been made to calculate the energy directly embodied in various uses, or for animate energy, the caloric value of food inputs. These calculations are difficult and not particularly useful, as the efficiency of energy use in these forms varies greatly from that of other fuels. Another alternative is to calculate the energy content of oil or other energy sources needed to perform the same tasks.

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72. See for example, United Nations Statistical Office, World Energy Supplies, Statistical Papers Series J (New York, UN), various issues; and International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979).

In general, the more energy sources differ in form and the uses to which they are put, the greater the difficulty of defining common units for measuring their use which also convey some impressions of their useful energy contribution. As a result, the greater the diversity of energy sources and uses, the greater the need for caution in interpretation of data using these common units. In particular, comparisons of aggregate total energy use and of the shares of different fuels in aggregate total energy consumption may be misleading. Table B-1 presents estimates of the efficiencies with which different fuels are used, by sector. We may use these efficiency coefficients to estimate "useful" energy consumption by sector. For example, column 1 in table B-2 presents a breakdown of 1975 total energy use in the Indian transport sector by fuels as presented in International Energy Agency data. In contrast to the transport sector in most developing countries, coal appears to play an extremely important role, contributing more than half of total energy use in transport. Column 3 presents estimates of the efficiency of energy use by fuel in transport, calculated for industrial countries. Assuming roughly similar efficiencies are achieved in India, the share of coal in useful energy consumption in transport appears much lower than its share in total energy consumption in transport--less than one-fifth, instead of one-half. The role of coal is thus dramatically overstated by comparisons of the total energy content of different fuels used in transport.

Table B-1. Efficiencies of Different Fuels, by Sector

Fuel	Sector		
	Domestic	Transport	Industry, except energy
Solid	0.20	0.044	0.70
Liquid	0.60	0.22	0.80
Gas	0.70	0.22	0.85
Electric	0.95	0.40	0.99

Source: William D. Nordhaus, "The Demand for Energy: an International Perspective," in William D. Nordhaus, ed., Proceedings of the Workshop on Energy Demand, May 22-23, 1975 (Laxenburg, Austria, International Institute for Applied Systems Analysis, 1976) p. 527.

Table B-2. Comparisons of Total and Useful Energy Consumption by Energy Source, Indian Transport Sector, 1975

	(1) Final energy consumption in transport, (thousands of tons of oil equivalent)	(2) Share in total energy consumption in transport	(3) Efficiency of use	(4) Useful energy consumption in transport (thousands of tons of oil equivalent	(5) Share in useful energy consumption in transport
Coal	9218	52.1	.044	406	17.7
Petroleum products	8301	46.9	.22	1826	79.5
Electricity	162	0.9	.40	65	2.8

Sources: Energy Data: International Energy Agency, Basic Energy Statistics and Energy Balances of Developing Countries, 1967-1977. Proceedings of Workshop on Energy Data of Developing Countries, December 1978, vol. II (Paris, OECD, 1979) p. 202; Efficiency Data: William D. Nordhaus, "The Demand for Energy: An International Perspective," in William D. Nordhaus, ed., Proceedings of the Workshop on Energy Demand, May 22-23, 1975 (Laxenburg, Austria, International Institute for Applied Systems Analysis, 1976) p. 527

Appendix C

PER CAPITA ENERGY RESOURCES OF DEVELOPING COUNTRIES

Table C-1. Per Capita Energy Resources of Developing Countries[a]

	Oil (tce)	Coal (tce)	Gas (tce)	Hydroelectric power[b] (tce)	Fuelwood status[c]
Afghanistan	--	--	--	0.22	A
Algeria	100.7	--	284.9	0.15	B
Argentina	19.1	11.0	22.4	0.98	B
Bangladesh	0.1	6.1	4.2	0.01	A
Benin	--	--	--	0.29	A
Bolivia	5.9	--	42.8	1.82	B
Brazil	2.1	67.8	0.8	0.40	B
Burma	0.2	--	0.1	1.25	A
Burundi	--	--	--	--	A
Cameroon	3.6	--	5.3	1.52	A
Central African Republic	--	--	--	3.12	A
Chad	--	--	--	0.43	A
Chile	7.9	15.1	17.3	0.79	B
Colombia	5.8	17.3	7.7	1.05	B
Congo	56.0	--	60.5	3.23	A
Costa Rica	--	--	--	1.10	B
Dominican Republic	--	--	--	--	B

Table C-1 (continued)

	Oil (tce)	Coal (tce)	Gas (tce)	Hydroelectric power[b] (tce)	Fuelwood status[c]
Ecuador	29.6	--	7.0	1.44	A
Egypt	16.3	--	5.0	0.05	A
El Salvador	--	--	--	0.11	A
Ethiopa	--	--	--	0.16	A
Ghana	0.1	--	0.2	0.08	A
Guatemala	0.5	--	--	0.10	B
Guinea	--	--	--	0.67	A
Haiti	--	--	--	--	A
Honduras	--	--	--	0.76	A
India	0.5	52.3	0.5	0.06	A
Indonesia	14.8	10.5	6.0	0.12	A
Ivory Coast	--	--	--	0.05	B
Jamaica	--	--	--	--	B
Jordan	--	--	--	--	B
Kenya	--	--	--	0.49	A
Korea	--	10.5	--	--	B
Laos	--	--	--	--	A
Lebanon	--	--	--	--	B
Lesotho	--	--	--	0.20	A
Liberia	--	--	--	1.89	A
Madagascar	--	--	--	4.13	A

Table C-1 (continued)

	Oil (tce)	Coal (tce)	Gas (tce)	Hydroelectric power[b] (tce)	Fuelwood status[c]
Mali	--	--	--	0.30	A
Malawi	--	--	--	0.01	A
Malaysia	44.2	--	66.3	0.05	B
Mauritania	--	--	--	0.71	A
Mexico	100.3	13.4	44.1	0.17	B
Morocco	--	--	--	0.03	A
Nepal	--	--	--	3.15	A
Nicaragua	--	--	--	0.77	B
Niger	--	--	--	1.03	A
Nigeria	45.3	1.1	18.2	0.01	A
Pakistan	0.5	--	7.3	0.14	A
Panama	--	--	--	0.71	B
Papua New Guinea	--	--	--	3.28	B
Paraguay	--	--	--	1.11	B
Peru	8.2	6.3	4.0	0.40	B
Philippines	0.1	--	--	0.09	A

Table C-1 (continued)

	Oil (tce)	Coal (tce)	Gas (tce)	Hydroelectric power (tce)	Fuelwood status
Portugal	--	--	--	0.34	B
Rwanda	--	--	--	--	A
Senegal	--	--	--	0.44	A
Sierra Leone	--	--	--	0.49	A
Somalia	--	--	--	0.03	A
Sri Lanka	--	--	--	0.04	A
Sudan	--	--	--	0.49	A
Syria	51.9	--	6.5	0.07	B
Tanzania	--	--	--	0.66	A
Thailand	--	--	6.4	0.08	A
Togo	--	--	--	0.11	A
Trinidad/Tobago	133.6	--	284.1	--	B
Tunisia	18.0	--	9.4	0.00	B
Turkey	0.6	18.4	--	0.19	B
Uganda	--	--	--	0.52	A
Upper Volta	--	--	--	1.15	A
Uruguay	--	--	--	0.46	B
Yemen Arab Republic	--	--	--	--	A
Yugoslavia	2.6	384.8	2.9	0.41	B
Zaire	1.1	--	2.5	2.64	A
Zambia	--	0.9	--	0.39	A

Table C-1 (continued)

Sources: Reserves: World Bank, Energy in the Developing Countries (Washington, D.C., World Bank, August 1980) pp. 5, 80-86; Population: World Bank, World Development Report 1980 (Washington, D.C., World Bank, August 1980) pp. 110-11.

[a]No proven reserves or information not available.

[b]Annual energy potential per capita under conditions of average flow from installed and installable capacity, utilized twelve hours per day, expressed in tons of coal equivalent. Conversion assumes tce per year = 536.1 x potential capacity in megawatts. (Based on assumption of 1 mwh = .122 tce).

[c]A indicates that the country has an actual or potential fuelwood problem. Countries "were placed in this category if estimated annual consumption of fuelwood could not be sustained through the year 2000, without damage to the ecology, at a level of .73 m^3 per capita where income per head (in 1978) was below $300, falling linearly to .50 m^3 at $600 and zero at $900. Many countries not included in this group have or will have fuelwood problems in local areas." (World Bank, Energy in the Developing Countries (Washington, D.C., World Bank, August 1980), p. 5. B indicates that the country is not in this group.

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