Chapter 4

Energy Supplies in the Developing World

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Introduction and Summary

This chapter provides an overview of the energy ***supply*** sector in the developing world—the processes and technologies by which energy is produced, converted from one form into another, and delivered to users. The energy supply sector is critical for economic development for two reasons: first, economic growth depends on the availability of reliable sources of energy; and second, the energy supply sector absorbs a large share of investment--over 40 percent of the total public investment in some developing countries,[1] and about 15 percent of foreign assistance.[2] The energy supply sector also relies heavily on other resources that can be scarce in the developing world, including skilled labor and management, water, and land.

The energy supply sector is critical to economic development. Economic growth depends on the availability of reliable sources of energy, and the energy supply sector absorbs a large share of public and foreign aid investment.

The developing countries use a wide range of energy sources. Coal is the largest primary energy source in developing countries, due mainly to the coal-based energy sectors of China and India, the two largest energy consumers in the developing world. Excluding China and India, oil and electricity are the mainstays of commercial energy supplies in developing countries. In rural and poor urban areas, traditional biomass fuels are the primary energy source.

Although the developing world as a whole is a net oil exporter, the exports originate from a relatively small number of countries. Most of the countries in the developing world depend heavily on imported oil, and these imports consume a large fraction of export earnings.

The commercial energy supply system--coal, oil and gas, and electricity-requires large amounts of foreign exchange, skilled labor, and trained management. It is characterized by state ownership, in contrast to supplies of traditional fuels, which are largely in private hands.

Commercial energy supplies in many countries are unreliable and of poor quality due to operational inefficiencies, rapid increases in energy demand, problems of reaching dispersed populations served by inadequate transport systems, and inappropriate pricing and allocation systems.

Operational efficiencies in the energy industry are somewhat lower in many developing countries than in the industrial countries. This record of "poor" performance often reflects the older equipment and difficult conditions under which energy facilities operate. The existence of such differences between operational efficiencies in reasonably standardized operations suggests that improvements are possible if some of these obstacles can be overcome.

Generalizations about energy supplies in developing countries obscure the heterogeneity of the developing world. Performance standards vary considerably between countries, as do prospects for expanding energy supplies in the future.

The Overall Primary Fuel Mix

According to the International Energy Agency (IEA), coal supplied 35 percent of the developing world's primary energy[3] in 1987 (table 4-1 and figure 4-l), followed by oil (31 percent), biomass fuels (19 percent), primary electricity (mostly hydropower) (8 percent), and natural gas (7 percent). Some analysts believe instead that biomass is in fact the largest source of energy, supplying up to one-third of primary energy in the developing world.

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[1] M. Munasinghe, *Electric Power Economics* (London: Butterworths, 1990).

World Bank, *Annual Report 1989* (Washington, *DC: 1989).* Data include ordy International Development Authority (IDA) and International Bank for Reconstruction and Development (IBRD) lending in fiscal year 1989.

[3] "Primary energy" refers to fuels in their raw state, before they are processed into forms suitable for use by final consum ers. Primary fuels include coal, oil, gas, biomass, and electricity generated from nuclear, hydro, geothermal, and solar sources. "Final energy," suitable for end-use consumption, includes electricity generated from fossil fuels as well as primary electricity. For countries with fossil fuel electricity generation facilities, the amount of electricity in the final energy mix is therefore higher than in the primary energy mix, and the amounts of fossil fuels are lower by the amounts used to generate electricity. Electricity generated from fossil fuels is not included in primary energy in order to avoid double counting.

Table 4-l—Energy Supply Mix, 1987 (percent)

Fuel	China	India	Brazil	Rest of developing world	Total developing world	United States
coal	70	38	6	17	35	24
Oil	17	22	38	41	31	41
Natural gas	2	3	2	12	7	22
Other	4	5	26	8	8	9
Biomass fuels[b]	7	33	28	22	19	4
Total (percent)	100	100	100	100	100	100
Total (exajoules)	26.7	9.6	6.9	42.0	85.2	77.9

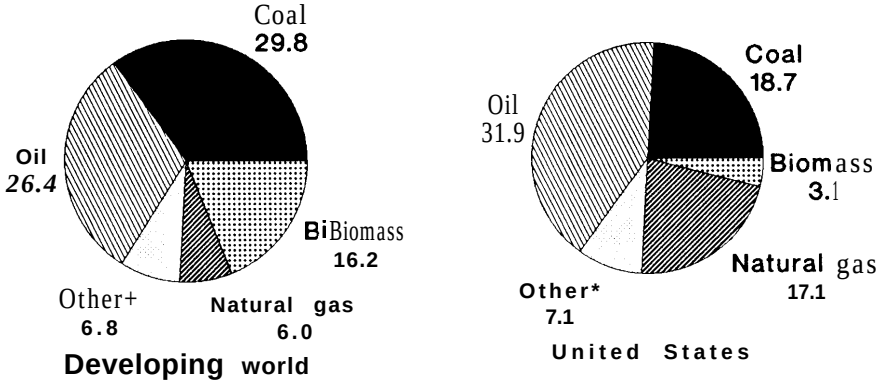
a Includes hydropower, nuclear, geothermal, solar, and electricity produced from biomass. Converted at heat equivalent.

b Note that these estimates for the share of energy supplied by biomass are lower than that indicated by detailed field surveys. See, for example, figure 3-1 and app. 3-A.

NOTE: Total may not add to 100 percent due to rounding.

SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971 -1987 (Pans: OECD, 1989); IEA, *Energy Balances of OECD Countries 1987-1988* (Paris: OECD, 1990).

Figure 4-l—Energy Supply Mix in the Developing World and in the United States, 1987 (exajoules)



"Includes hydropower, geothermal, other renewable, and nuclear converted at heat equivalent. Biomass numbers may be underestimates, see text, and alternative source, figure 1-2.

SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971- 1987 (Paris: OECD, 1989); IEA, *Energy Balances of OECD Countries 1987-1988* (Paris: OECD, 1990).

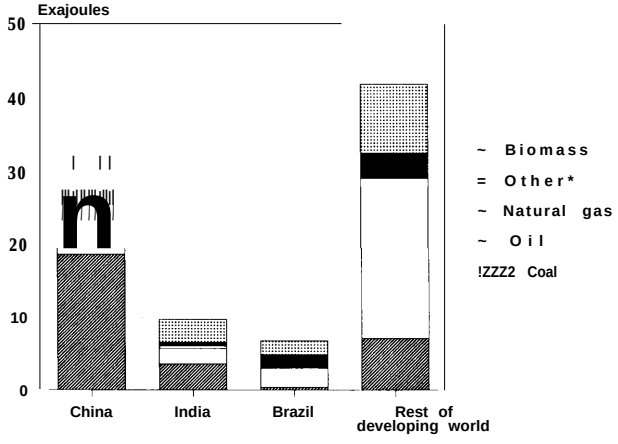
The relative shares of these energy sources in the overall energy supply mix vary significantly across different regions and countries, due in part to unequal endowments of energy resources. Coal supplies about half of the energy requirements for developing countries in Asia, due largely to high levels of coal consumption in China and India[4] (table 4-1 and figure 4-2). Oil is the major source of commercial primary energy for most countries of the developing world, India and China being the notable exceptions. Natural gas supplies a relatively small fraction of energy in the developing world, although in countries with well-developed resources, gas often represents an important source of energy (in Mexico, for example, natural gas supplies 20 percent of the primary energy consumed).[5] Biomass fuels are a significant energy source throughout the developing world, particularly in rural areas and in the poorest countries.

Overall, the developing world produces more energy than it consumes, and significant amounts of both oil and gas are exported from developing countries (figure 4-3). There are, however, major disparities among countries: only a few developing countries export energy, and most import over 50 percent of the commercial energy they consume.

[4]International Energy Agency @A), *World Energy Statistics and Balances 1971-1987* (Paris: OECD, 1989), using 1987 data. This includes IEA estimates for biomass consumption and converts electricity to energy units at the heat equivalent,

[5]Ibid.

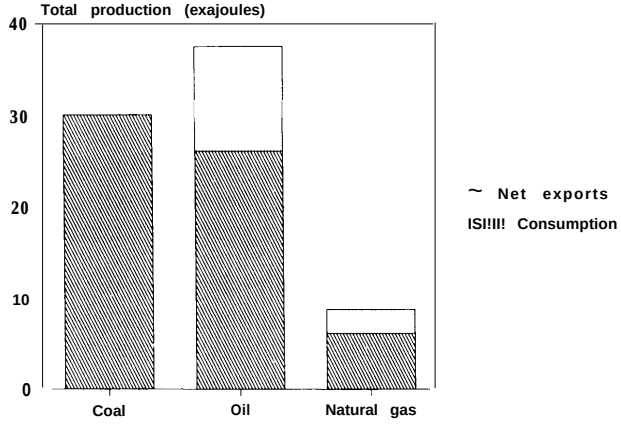
Figure 4-2—Energy Supply Mix for Selected Regions of the Developing World, 1987



'Includes hydropower, geothermal, other renewable, and nuclear converted at best equivalent. Biomass numbers maybe underestimates, see text.

SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971 -1987 (Pans: OECD, 1989).

Figure 4-3-Primary Energy Production, Consumption, and Exports in the Developing World, 1985



SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971 -1987 (Paris: OECD, 1989).

Coal

Coal production and consumption in the developing world are concentrated in a relatively small number of countries. China, India, South Africa, South Korea, and North Korea are responsible for 96 percent of the total coal production in the developing world. China alone accounts for 65 percent of developing world coal production and 27 percent of world coal production.[6]

The largest consumer of coal in the developing world is industry, which accounts for over 40 percent of total developing world coal use.[7] The bulk of the industrial coal use is in China. Other significant coal-consuming sectors are electric utilities, transportation (coal-burning locomotives), and the residential sector in China, where coal is used for cooking and space heating.

Rates of coal production are growing rapidly. Hard coal production in Asia grew at an average annual rate of 5.7 percent from 1980 to 1987, and lignite production grew at 8.9 percent during the same period.[9] This growth is expected to continue.

Coal quality in the less developed world varies widely, both within and among countries.[10] In India and China, most coal has a relatively low sulfur content but a high ash content.[11] There are few washing and sorting processes at coal mines, so the quality of coal supplies is unpredictable. In China, for example, less than one-fifth of all coal mined is cleaned before combustion. The rest is used raw, limiting the efficiency of combustion.

The coal industry accounts for about 16 percent of total commercial energy investment requirements in low-income developing countries.[12] In India and China, the largest coal users, domestic sources finance most of this investment.

Government-owned entities are responsible for most coal mining, transport, and distribution in developing countries. In China, the Ministry of Coal

[6]Ibid., p. 59, 1987 production of hard coal only.

[7]Ibid., 1985 data. The United States, in contrast, uses most of its coal for electricity generation.

[8]As shown in figure 4-3, net coal exports are insignificant, so for the developing world as a whole coal production is the same as coal consumption. Some individual developing countries do trade incoal—e.g., South Africa is a coal exporter and the Republic of Korea is a coal importer.

[9]IEA, op. cit., footnote 4.

[10]The important attributes of coal quality are energy density (typically measured in Joules per kilogram or Btu per pound), sulfur content, and ash content.

[11]Tata Energy Research Institute, *TERI Energy Data Directory and Yearbook 1988* (New Delhi, India: 1989); Vaclav Smil, "China's Energy," contractor report prepared for theOffice of Technology Assessment, 1990.

[12]World Bank, *The Energy Transition i, Developing Countries* (Washington, DC: *1983), p.* 68. For period 1982-92.

Industry controls about 600 of China's 20,000 mines, grouped under 84 Coal Mine Administrations or Coal Industry Companies. The remaining, mostly smaller mines are run through local governments at the provincial, county, or prefecture level, or as collective township and village enterprises. In India, the government-owned Coal India Corp. accounts for 87 percent of production. Coal India, with 675,000 employees, claims to be the world's largest single corporate employer.[13] The allocation of supplies is also in the hands of a government entity.

Although coal mining technologies in the developing world are diverse, the major coal producer -China-relies heavily on manual labor.[14] About two-thirds of the extraction from large mines in China depends on manual labor, as does virtually all production from locally run mines and small private pits. Not surprisingly, labor productivities are very low, averaging less than 1 ton per miner per shift. This rate is significantly lower than current U.S. rates, which average about 10 tons per miner per shift.15

Although China has considerable experience with a wide variety of advanced underground mining techniques and has the ability to produce most of the machinery required, the country does not have sufficient capital or technical expertise to modernize its coal industry completely. However, surface extraction methods, which can be less expensive, are being used at many newly developed sites. Five large pits are now under development in China with a total initial capacity of 50 million tons per year. The largest of these should eventually produce up to 60 million tons per year.

Transportation requirements often limit coal production. In China, coal accounts for 40 percent of all freight movement, most of which is by rail. China's already overloaded transport system is struggling to keep up with its growing coal production. Incomplete and poorly configured networks, backups at mode transfer points, and breakdowns all contribute to the unreliability of the coal transport system. As a result, coal-using industries must stockpile up to a year's supply, or turn to other fuels. Similar problems occur in India.[16]

Oil

Petroleum products are easy to transport and versatile in use in all sectors and at all scales of operation; consequently, they play an important role in the energy sectors of developing countries. These attributes led to an average annual growth rate of 4.5 percent for oil consumption in the developing world from 1971 through 1987.[17] Oil consumption is expected to continue rising by about 3 percent per year, thereby doubling between 1985 and 2010.[18]

More than one-third of the oil consumed in the developing world is used for transportation (figure 4-4 and table 4-2). The share of oil used for transportation varies from 13 percent in China to 42 percent in Latin America--considerably lower than the 62 percent share in the United States. The developing world, compared to the United States, uses proportionally more oil for electricity generation and for industry. The entire developing world consumes about 25 percent less oil than the United States alone.

The bulk of developing world oil production is concentrated in a few countries—14 developing countries account for over 90 percent of developing world oil production.[19] Although the developing world as a whole is a net oil exporter, the exports originate from a relatively small number of countries.[20] Most developing countries depend heavily on oil imports. More than half of the low- and lower middle-income countries import 90 percent or more

[13] IDEA, Inc., "Clean Coal Technologies for Developing Countries," contractor report prepared for the Office of Technology Assessment, May 1990.

[14] This discussion is drawn from Vaclav Smil, "China's Energy," op. cit., footnote 11.

[15] Relative to the United States, labor is cheaper and mechanization is more expensive—so one would expect greater use of labor inputs and less mechanization in China than in the United States.

[16] For example, one textile mill in India is converting from coal to rice husks as a boiler fuel because of the extreme unreliability of coal supplies (V. Kothari, consultant, Isotem Services, New Delhi, India, personal communication, April 1990).

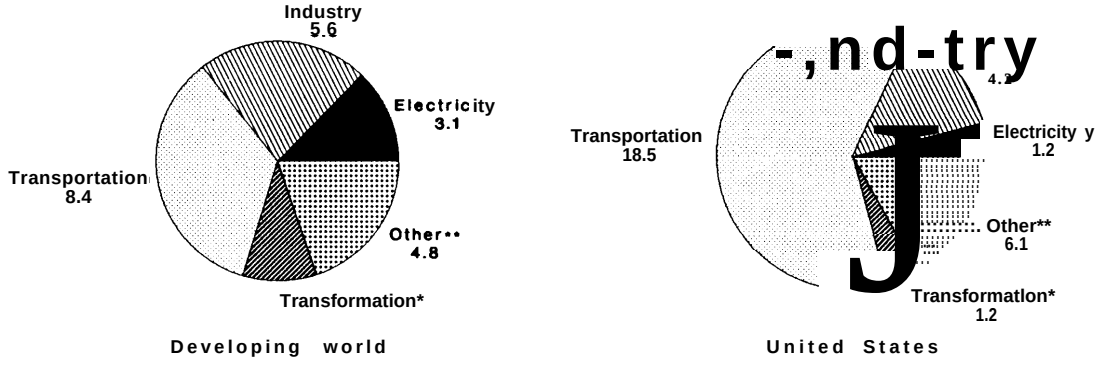
[17] IEA, op. cit., footnote 4.

[18] Alan S. Manne and Leo Schrattenholzer, *International Energy Workshop: Overview of Poll Responses* (Palo Alto, CA: Stanford University, July 1989) International Energy Project.

[19] These are, in order of decreasing oil production Mexico, China, Venezuela, Indonesia, Nigeria, Algeria, Libya, Egypt, Brazil, India, Malaysia, Argentina, Colombia, and Angola. IEA, op. cit., footnote 4.

[20] Five countries-Mexico, Nigeria, Venezuela, Libya, and Indonesia-account for over 60 percent of LDC oil exports. IEA, op. cit., footnote 4.

Figure 4-4-Oil Consumption by End Use in the Developing World and in the United States, 1985 (exajoules)



*Refinery use and losses.
● *Residential, agricultural, and nonenergy.

SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971 -1987 (Paris: OECD, 1989) IEA, *Energy Balances of OECD Countries 1970/1985* (Pans: OECD, 1987).

Table 4-2-Oil Consumption by End-Use Sector, 1985 (percent)

Sector	Asia[a]	China	Africa	Latin America	Total developing world	United States
Electricity	12	15	13	12	13	4
Transformation[b]	10	10	5	10	10	4
Industry	24	40	18	16	23	14
Transportation	35	13	41	42	35	62
Other[c]	16	19	17	16	16	11
Nonenergy[d]	3	4	6	4	4	6
Total (percent)	100	100	100	100	100	100
Total (exajoules)	7.5	3.9	3.5	9.1	24.0	29.9

a excluding China.
transformation includes losses, refinery use, and statistical differences.
c Other is largely residential and agriculture.
d Non-energy use includes waxes, asphalt, and lubricants.
NOTE: Totals may not add to 100 percent due to rounding.

SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971 -1987 (Paris: OECD, 1989); IEA, *Energy Balances of OECD Countries 1970/1985* (Paris: OECD, 1987).

of their commercial energy; almost all of the imports are in the form of oil (see app. 1A). By comparison, the United States imports about 17 percent (net) of its energy, of which 90 percent is in the form of oil or oil products.[21] The continued expansion Of oil consumption imposes an economic burden on developing countries, either in the form of foreign exchange for imported oil or for investment in oil exploration and development. Investment in the oil supply infrastructure is comparable with that in the electricity sector, each accounting for about 40 percent of total commercial energy investment in the developing world.[22]

In most developing counties, natural resources such as oil and gas are considered state property. Ownership or other economic rights to these natural resources are not bought and sold with the surface rights (as in the United States), but are reserved for the state to exploit or to contract out to third parties. Inmost oil-exporting developing countries, supreme authority over oil and gas is legally vested in a central government entity-(e.g., the Ministry of Oil in Egypt or the Ministry of Petroleum and Minerals in Oman), which delegates sectoral oversight and operational responsibility to a national oil company (e.g., the Egyptian General Petroleum Corp.). In

[21]Energy Information Administration (EIA), *Monthly Energy Review December 1989,* DOE/EIA-0035(89/12) (Washington, DC: *Us.* Government *Printing* Office, February 1990).

[22]World Bank, op. cit., footnote 12, p. 68.

practice, however, there are wide disparities among different countries in the actual relationships among executive power, sectoral ministries, and national operating entities. In oil-exporting countries, such as Argentina and Algeria, the national operating companies have more power than the ministries they depend on, due to the companies' autonomous sources of revenue from significant oil production. In contrast, in oil-importing countries, such as Sudan, the national oil companies have little power.

Only the wealthier oil-exporting developing countries invest much of their own money in exploration and development. All the poorer ones, and the majority of the others, rely on the international oil industry for most of the required capital and technical expertise. The "enabling mechanism" under which foreign oil companies invest in developing countries varies widely from country to country, but certain aspects are widespread. Generally, the ministry in charge of the sector authorizes the national oil company to negotiate exploration rights with foreign companies. This negotiation may require the formation of a formal joint venture with the national company. More typically, however, a loose relationship is formed in which the two associates remain entirely separate, with the foreign party providing all the capital and most of the technical control of operations. Once a deal is concluded, it is ratified at the central government level.

The fiscal arrangements made under these enabling mechanisms have in the past been inflexible, providing for the same overall rate of government take on all sizes of fields. These arrangements are satisfactory for the middle range of expected reserves and costs. When oil fields are larger than expected, however, the government fails to capture a reasonable share of the profits on the petroleum being produced. When fields turn out smaller then expected-a typical occurrence in many developing countries-the government share precludes economic development by the foreign operator. This discourages the development of small fields. A further discouragement to foreign oil companies for the development of oil fields for domestic consumption rather than export is uncertainty over the availability of foreign exchange for the remittance of profits.

Despite these disadvantages, U.S. oil companies in recent years have increased their investments outside North America, particularly in developing countries. The prospect of adding to corporate reserves at half the cost of domestic exploration[23] apparently more than compensates for the uncertainty of foreign investment.

Refineries and Distribution

Although the world's oil refining capacity is concentrated in the industrialized countries, many of the developing countries, including oil-importing countries, have considerable domestic refining capacity. Over half of the countries in Africa have refineries,[24] many of which are hydroskimmers (see box 4-A). In the developing world, refineries are usually owned by the government, which acts through a national oil company, although foreign companies sometimes manage and operate the refineries.

The refinery product mix in developing countries differs significantly from that in the United States, due in part to the inflexibility of the hydroskimming technology. In developing countries, between 60 and 70 percent of refinery output is diesel and residual, compared with 30 percent in the United States. On the other hand, gasoline accounts for about half of U.S. production, compared with about 20 percent in developing countries.[25] In general, refineries in developing countries have higher production costs than those in the industrialized world: average refinery operating costs in Africa are $2 per barrel, compared to $0.75 per barrel in the rest of the world.[26] Refineries in the developing world also suffer from large losses due to the use of old, inefficient technology, as well as poor maintenance. Refinery losses, which should not exceed 1 percent

[23] The cost of finding a barrel of oil in the United States is $6, compared with $3 in the rest of the world (Solomon Brothers Inc., *Proved Petroleum Reserves of 30 Large Energy Companies 1980-87* (New York, NY: 1988), p. 14.

[24] United Nations, *1986 Energy Statistics Yearbook (New* York, NY: 1988).

[25] Ibid.

[26] T. Gorton, "Oil and Gas Development in Third World Countries," draft contractor report prepared for the Office of Technology Assessment April 1990.

Box 4-A—Refinery Technology

Crude oil is a mixture of hydrocarbons. In the simplest refining process, primary distillation (also known as hydroskimming), crude oil is simply heated. This causes the lightest hydrocarbons, such as gasoline and liquid petroleum gas, to boil off first. As the temperature increases, different products (such as kerosene and diesel oil) boil off. The residual, known as residual fuel oil, remains. This relatively simple process does not allow for much flexibility in the mix of yielded products. For example, 18 to 23 percent gasoline and 30 to 55 percent residual fuel oil are typical yields from primary distillation.[1]

Secondary conversion, which includes fluid catalytic cracking (FCC) and hydrocracking, uses high temperatures to "crack" large molecules into smaller ones. This process allows for greater flexibility in product mix, and is often used to increase the proportions of lighter hydrocarbons, such as gasoline and LPG, while reducing the proportion of residual fuel oil. For example, hydrocracking allows for up to 86 percent (by weight) gasoline production, compared with 18 to 23 percent for primary distillation.[2] However, secondary cracking is relatively expensive and complex.

[1]L. Wijetilleke and A. Ody, "World Refinery Industry—The Need for Restructuring," World Bank Technical Paper No. 32, Washington DC, 1984, p. 32a.

[2]Ibid, p. 33a.

in a properly maintained and operated refinery, often exceed 2 or even 4 percent in developing countries .27

During the 1970's and 1980's, both the structure and the level of petroleum product prices changed. As the prices of petroleum products increased, coal, gas, and hydroelectricity were substituted for residual fuel oil in electricity generation, leading to a relative decrease in the demand for residual fuel oil. When the gap between gasoline and diesel prices widened (due to diesel subsidies and/or gasoline taxes), consumers switched to diesel cars. As a result, the structure of demand for petroleum products changed in many countries; the demand for the middle distillates increased relative to the demand for gasoline at the top end and residual fuel at the bottom. Developing country refineries, which typically do not have secondary conversion technology, could not adjust to these changes. As a result, some of their surplus petroleum products had to be exported, often at distress prices, while other products had to be imported.[28]

Because of these developments in the international petroleum market, several developing countries are producing refined petroleum products at costs higher than those prevailing on the international market. Up until recently, for example, Liberia had only one refinery, which was poorly maintained, inefficient, and in need of upgrading. An economic analysis of this refinery showed that importing the refined petroleum products directly and shutting down the inefficient domestic refinery would result in net savings of $15 million to $20 million per year (U.S. dollars), equivalent to a gain of about 2 percent in Liberia's gross domestic product (GDP) .29 Several other African countries are in similar situations.

The distribution system for petroleum products plays a key role in determining whether or not the economy has sufficient and dependable fuel supplies. Because large portions of the population are scattered in rural areas, and transport infrastructures are frequently inadequate, the distribution systems in developing countries are often unreliable. In addition, price controls, supply monopolies, rationing systems, and requirements for uniform pricing in all areas may further limit the dependability of petroleum in developing countries.

Natural Gas

Natural gas plays a relatively minor role in the energy supply system in most developing countries, supplying only 7 percent of total energy use in the developing world (see table 4-l). This contrasts sharply with its role in the industrialized world. In the United States, for example, natural gas supplies 22 percent of domestic energy consumption. However, gas is an important source of energy for a small number of developing countries. Five countries—Mexico, Argentina, Venezuela, China, and Algeria—

[27]Refinery losses result from leakage, evaporation, and spills; they are distinct from "own use" consumption, which is oil intentionally consumed in the refinery process for heat, transport, and drive. See T. Gorton, op. cit., footnote 26.

[28]L. Wijetilleke and A. Ody, "World Refinery Industry-The Need for Restructuring," World Bank Technical Paper No. 32, Washington DC, 1984.

[29]T. Wilbanks and S. Wright, "Energy for Development: ORNL Returnsto the Third World," *ORNL Review, No. 3, 1988.*

account for 58 percent of developing world natural gas consumption. Natural gas consumption in the developing world is concentrated in industry, where it is used both as a fuel and as a feedstock. Natural gas is also used for electricity generation.

Discovered gas reserves in many developing countries are not developed. The current production levels from developed reserves are only 16 percent of the level that current proven reserves could sustain.[30] Thus, many developing countries import large quantities of crude or fuel oil while possessing reserves of natural gas that could serve more economically and with less harm to the environment.[31]

The reasons for the relative underutilization of natural gas in the developing world lie more in institutional than in technical or financial constraints. Although gas is associated with oil exploration and development and therefore shares many of the same problems, it has additional difficulties of its own. In the exploration phase, due to the fiscal or contractual terms under which gas is discovered, gas discoveries are often treated as "dry holes" by oil exploration companies.[32] In the development phase, gas requires heavy front-end capital investments (pipelines from producing to consuming regions, or, in the case of overseas trade, costly facilities and tankers to liquefy and transport the gas) and long-term agreements between suppliers and consumers. And the high cost of building distribution systems in cities deters the development of domestic markets for natural gas.

The specific requirements of gas development are particularly difficult for developing countries, where financing for large capital-intensive projects is hard to find, and where the main purchaser for the gas is the state. When the developer is a private foreign corporation, the problems are complicated by uncertainty that sufficient foreign exchange will be available for the investor to repatriate profits. This last difficulty is especially acute in the case of highly indebted developing countries where the bulk of scarce hard currency is earmarked in advance for payments on debt. Unlike the electricity sector, which shares many of these characteristics, development of natural gas reserves has generally not been financed by donor agencies.

Biomass Fuels

Biomass fuels are an important source of energy in the developing countries, supplying over three-fourths of the total energy consumed in almost all of the lower income developing countries.[33] The contribution of biomass fuels to total energy supplies in the entire developing world is unclear. Biomass fuel consumption is difficult to measure, as much of it never enters a commercial market. As shown in table 4-1, biomass fuels supply about 19 percent of total energy according to the International Energy Agency. Other researchers, however, estimate this number at 33 to 35 percent.[34]

Biomass fuels are the dominant energy source in rural areas, and they are also widely used in poorer urban areas, as well as in some large-scale industrial processes. These "traditional fuels" consist of wood (firewood and charcoal), dung (from cattle and other animals), and crop wastes (e.g., wheat, rice straw, and sugar cane bagasse). Wood is the most widely used and preferred fuel due to its superior combustion characteristics. Its share of total biomass energy supply varies widely among the developing countries, according to region and agricultural and forestry resource base. In many regions of Africa and Latin America (with the important exception of Brazil, where bagasse is also used), wood is the primary form of biomass energy used. In Asian countries, wood remains the dominant biomass fuel (accounting for one-half of all biomass consumed in

[30] World Bank, op. cit., foomote 12, p. 36.

[31] To mention @t the sub-Saharan African countries with undeveloped gas fields: Mozambique, Ethiopia, Somalia, Madagascar, Cote d'Ivoire, Equatorial Guinea, Sudan, Senegal, Tanzania, and Namibia.

[32] By one estimate, about half of the natural gas produced in the developing world is flared or otherwise wasted. The comparable number for Eastern Europe is 2 percent. A. Mashayekhi, "Natural Gas Supply and Demandin Less Developed Countries," *Annual Review of Energy, vol. 13, 1988,* pp. 119-129.

[33] The role of biomass fuels in the total energy supply varies greatly among countries, show@ generally an inverse relationship with GNP per capita. For example, Ethiopia (GNPper capita = $U.S. 130) meets 92 percent of its energy needs with biomass fuels, while Argentina(GNP per capita= $U.S. 2,390) meets only 7 percent of its needs with biomass fuels.

[34] K. Smith, "The Biofuel Transition," *Pacific and Asian Journal ofEnergy, 1987,* pp. 13-32; P. O'Keefe, J. Soussan, B. Munslow, and D. Spence, "Wood Energy in Eastern and Southern Africa," *Annual Review of Energy, vol. 14, 1989,* pp. 445-468.

China, and three-quarters in India), but crop wastes and animal dung also play a significant role.[35]

Biomass Resource Base

For a variety of reasons, the fuelwood supply base is shrinking rapidly. This could have serious impacts on the populations that depend on forests for fuel, food, fiber, fodder, and other needs.

The total global annual growth of forest biomass is subject to great uncertainty, but has been estimated to be about 50 times annual wood consumption or five times total annual energy consumption, including fossil fuels. Despite this apparently large average global supply, there are acute and growing shortages of fuelwood both locally and regionally. Some regions, such as Asia, have very little forest stock per capita (table 4-3). Within regions, some countries are well endowed with biomass energy resources, while others have totally inadequate supplies; and within countries themselves, local abundances and shortages are common. Zaire, for example, consumes only 2 percent of its sustainable yield of forest biomass but has serious deforestation around Kinshasa.[36]

Despite the uncertainties regarding rates of biomass energy use and supply, it is clear that the populations affected by fuelwood shortages are increasing. The United Nations Food and Agriculture Organization (UNFAO) has estimated that the number of people suffering acute shortages of fuelwood will increase from about 100 million in 1980 to over 350 million in the year 2000. Such shortages increase fuel costs for urban dwellers, lengthen the time spent foraging for fuel by rural dwellers, and rob the soil of nutrients as people switch from wood to crop wastes and dung (although the impact of this nutrient loss maybe limited except in the much longer term).

Rural Biomass Markets

Much of the biomass fuel supply in developing countries-especially twigs, branches, dung, and crop wastes—is gathered locally and used by family members without entering commercialized markets.

Table 4-3-Biomass Energy Resources in Selected Developing Countries

	Sustainable energy yield (GJ per capita per year		
Country	Wood	Crop residues	Animal dung
Congo	570	1	—
Brazil	350	8	16
Zaire	135	1	1
Argentina	123	25	40
Thailand	37	9	4
Nepal	21	7	13
Burkina Faso	10	5	7
India	7	5	6
Bangladesh	2	4	5
China	—	7	3

— data not available or not applicable

SOURCES: G. Barnard and L. Kristofferson, *Agricultural Residues as Fuel in the Third World* (London: Earthscan, 1985); D. Hall, G. Barnard, and P. Moss, *Biomass for Energy in the Developing Countries,* Pergamon Press, 1982. R. Moss and W. Morgan, *Fuelwood and Rural Energy Production and Supply in the Humid Tropics,* (Dublin, Ireland: Tycooly International Publishing Ltd, 1981).

These supplies are gathered free of charge (if the considerable cost of the labor used in gathering is not included) from fields, hedgerows, gardens, and nearby forest lands. In some cases, however, the poor may have to "pay" with labor services for the privilege of gathering biomass fuels from privately owned land.

Commercial Biomass Markets

Biomass fuels, notably logs and charcoal, are also traded in commercial markets far from their origin in government and private forests, farms, or plantations. Low-income urban households and small commercial enterprises use the bulk of these fuels. In some cases, however, biomass fuels are used for advanced industrial applications, as in the case of charcoal for iron smelting in Brazil. In such cases, the industrial users often organize the biomass fuel supplies.

Unlike other forms of energy, supplies of commercialized biomass fuels are largely in the hands of the private sector. Much of the fuelwood may be grown on privately owned land,[37] and the transport and distribution charnels for commercialized bio-

[35]Crop wastes account for one-half of total traditional energy supply in China and just over 10 percent in India. Animal dung accounts for about 20 percent of traditional fuel use in India, Pakistan, and Bangladesh but under 2 percent in China.

[36]R. Moss and W. Morgan, *Fuelwood and Rural Energy Production and Supply in the Humid Tropics* (Dublin, Ireland: Tycooly International Publishing Ltd., 1981).

[37]In several Indian cities, for example, government lands were found to provide less than 10 percent of total fuelwood supplies (M. Alam, J. Dunkerley, and A. Reddy, "Fuelwood Use in the Cities of the Developing World: Two Case Studies From Ire@" *Natural Resources Forum, vol. 9, No. 3, 1985).*

mass, fuels are typically in private hands, as are charcoal kilns.[38]

On the other hand, the fuelwood trade is often subject to government regulation, with strict rules about cutting trees in government forests and even on private lands. Although it is believed that such regulations are not strictly enforced, often because of the difficulty of enforcement, proscriptions against cutting trees can discourage the development of long-term supplies, as farmers and others are unwilling to invest in tree planting for fuelwood if they have no assurance that they can harvest the trees at maturity. Fuelwood prices may also be subject to price controls (in Senegal, for example, charcoal prices are controlled by the government). And in some cases, governments may play a role in the distribution system as well. Compared with commercial fuels, however, the biomass trade is relatively unregulated.

The transport of wood and charcoal to urban areas is carried out in a variety of ways. In India, poor women carry head loads of fuel to urban markets; in Niger, camels carry fuel into the capital city of Niamey; and elsewhere fuel is carried by bicycle, animal cart, moped, and other means. In higher income areas, trucks or trains carry the bulk of the fuel.

Charcoal

In rural areas, the cutting of fuelwood and its conversion to charcoal is a major source of income and nonagricultural employment. Charcoal is made by stacking the wood, covering it with a layer of dirt, and letting it burn with a limited supply of air. The efficiency of converting wood to charcoal in these simple earthen kilns is quite low, typically ranging from 40 to 60 percent.[39] If a capital investment is made, ranging from a few hundred dollars for simple modifications to traditional kilns[40] to $100,000 or more for a modern continuous retort, higher energy efficiencies can be achieved.

Although it is widely believed that charcoal is cheaper to transport than wood due to its higher energy content by weight, detailed studies have found that the transportation costs for wood and charcoal are about the same.[41] The higher energy content of charcoal per unit weight is counterbalanced by its lower weight per unit volume.

Despite its higher price, charcoal is widely used in some countries, particularly in urban areas where people have cash incomes. A 1970 report from Thailand, for example, indicated that 90 percent of the wood cut for urban markets was converted to charcoal.[42] It has several important advantages over wood. Charcoal is impervious to insect attack, unlike some wood species that must be used within as little as a month of drying to avoid significant losses to termites.[43] As it is nearly smokeless, charcoal cooking can be done indoors in relative comfort without blackening walls or metal pots with soot. In addition, charcoal causes little smoke irritation to eyes or lungs. Although it can emit large amounts of dangerous carbon monoxide and other pollutants, which is a health hazard in poorly ventilated kitchens, charcoal causes little obvious discomfort to the user. Additionally, once lit, charcoal fires need little attention from the cook, whereas wood fires require frequent adjusting of the fuel.

Biomass Pricing

When people move from rural to urban areas in developing countries, they typically continue to follow traditional patterns of biomass fuel use. In contrast to the labor-intensive collection of biomass fuels in rural areas, however, the urban poor often have no choice but to purchase fuelwood or charcoal in commercial markets. In Tanzania, the cost of purchasing these fuels reportedly ranges as high as

[38] M. Alam, J. Dunkerley, and A. Reddy, Ibid.

[39] *Charcoal* Production *Improvement for Rural Development in Thailand* (Bangkok, Thailand: Royal Thai Government and U.S. Agency for International Development, 1984); D. Earl, *Charcoal Production, Sudan Renewable Energy Project,* Energy Research Council, USAID, Report No. 002, Khartoum, Sudan, February 1984; J. Wartluft and S. White, *Comparing Simple Charcoal Production Technologies for the Caribbean* (Arlington, VA: Volunteers in Technical Assistance, 1984).

[40] K. Christophersen, G. Karch, and J. Seve, "Production and Transportation of Fuelwood and Charcoal From Wood Surplus to Deficit Regions in Niger: Technical and Economic Feasibility" (Washington DC: Energy/Development International, March 1988).

[41] T. Wood and S. Baldwin, "Fuelwood and Charcoal Use in Developing Countries," *Annual Review of Energy,* vol. 10, 1985, pp. 407-429.

[42] J. Arnold, "Wood Energy and Rural Communities," *Natural Resources Forum,* vol. 3, 1979, pp. 229-252.

[43] Simon Nkonoki and Bent Sorensen, "A Natural Energy Study in Tanzania: The Case of Bundilya Village," *Natural Resource* Forum, vol. 8, No. 1, 1984, pp. 51-62.

40 percent of the income of poor families.[44] More typically, energy accounts for 5 to 10 percent of the expenditures of poor households.[45]

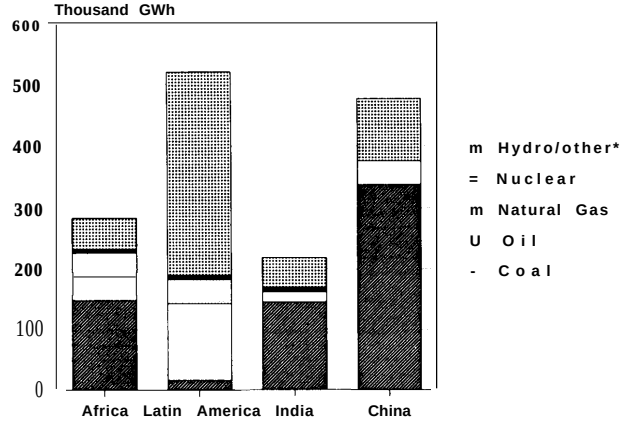
Biomass fuel prices in urban markets often rise rapidly as wood resources are seriously depleted, and then closely follow fossil fuel markets. Biomass costs cannot rise very far above the cost of an equivalent amount of useful energy from kerosene or LPG, as users can and will then switch fuels.[46] Families that purchase modern stoves and fuels, however, rarely discard the older stoves. Maintaining both technologies allows easy and flexible switching between fuels in response to availability and price. Following the 1973 and 1979 oil price increases, for example, many people switched back to wood and charcoal for their cooking needs. In Malawi the use of kerosene, primarily for cooking and lighting, declined by 24 percent between 1973 and 1976.[47]

Electricity

Electrification plays a central role in promoting economic and social development in any nation. At the same time, the electricity sector consumes large amounts of economic, social, and environmental resources. Accordingly, the electric power sector receives significant attention and resources from both developing country governments and international development agencies. For example, the World Bank directs over 80 percent of its energy lending to the electricity sector.

Although electricity accounts for less than 9 percent of the energy used by consumers in developing countries,[48] electricity production in the developing world is increasing rapidly, at an average annual rate of 7.6 percent.[49] However, this rapid growth still leaves the developing world at a far lower level of electricity production than the industrialized world: average annual electricity production in the developing world is about 520 kilowatt-hours (kWh) per capita,[50] as compared with the U.S. figure of 10,500 kWh per capita.[51]

Figure 4-5--Electricity Generation by Fuel Type in Selected Regions of the Developing World, 1987



'Includes hydropower, geothermal, and other renewable.

SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971-1987 (Paris: OECD, 1989).

Electricity Generation

In the developing world, as in the United States, a variety of fuels and technologies are used for electricity generation (see figure 4-5 and table 4-4).

Coal use for electricity production in the developing world is concentrated, largely in countries with sizable domestic coal reserves (India, China, and South Africa). Similarly, natural gas generating capacity is found mainly in the few countries where natural gas is produced domestically. In other countries, oil is often used for electricity generation.

Hydroelectric facilities range from microhydropower stations with less than 0.1 megawatt (MW) of capacity to large-scale hydropower plants such as the 12,600 MW Itaipu facility in Brazil. For countries with hydroelectric potential, hydropower offers an indigenous source of electricity generation with very low operating costs, although the capital costs

[44]E.M. Mnzava, "Village Industries vs. Savannah Forests," *UNASYLVA*, vol. *33, No. 131, 1981,* pp. *24-29.*

[45]Gerald Leach and Marcia Gowen, *"Household* Energy Handbook," World Bank Technical Paper No. 67, 1987, p. 50.

[46]Douglas F. Barnes, "Understanding Fuelwood Prices in Developing Nations," World Bank, Household Energy Unit, Industry and Energy Department, Oct. 31, 1989.

[47]J. Arnold, "Wood Energy and Rural Communities, " *Natural Resources Forurn, vol. 3, 1979,* pp. 229-252.

[48]IEA, op. cit., footnote 4, pp. 112, 120, 124, 128.

[49]For the period 1971-87. IEA, op. cit., footnote 4.

[50]U.S. Agency for International Development *PowerShortages in Developing Countries: Magnitude, Impacts, Solutions and the Role of the Private Sector* (Washington, *DC:* Office of Energy, U.S. AID, March 1988), p. 2.

[51]Energy Information Administration, *Annual Energy Review*, DOE/EIA-0384(88) (Washington, DC: U.S. Government Printing Office, 1989).

Table 4-4-Electricity Generation by Fuel, 1987 (percent by kWh delivered)

Fuel	Africa	Latin America	China	India	United States
coal	52	3	68	66	57
oil	14	24	12	8	5
Natural gas	14	8	*	1	11
Nuclear	3	1	0	2	18
Hydro/other[a]	18	63	20	23	10
Total (percent)	100	100	100	100	100
Total(GWh)	283,340	520,290	497,320	217,500	2,732,530

*Less than 1%.
a Includes hydropower, geothermal, and other renewables.
NOTE: Does not include heat losses. Totals may not add to 100 percent due to rounding.
SOURCE: International Energy Agency. *World Energy Statistics and Balances 1971-1987* (Paris: OECD, 1989); IEA, *Energy Balances of OECD Countries 1987-1988* (Paris: OECD, 1990).

are high. In Latin America, hydropower plays a large role, supplying almost two-thirds of total electricity.[52] More than 90 percent of Brazil's total electricity supply comes from hydropower.[53] In Africa, almost half of the electricity generated outside of South Africa comes from hydropower,[54] and more than two-thirds of the countries in Africa produce electricity from hydroelectric plants.[55]

Only eight developing countries were generating electricity from nuclear powerplants as of late 1989,[56] although several more have plants planned or under construction.[57] Nuclear power generation involves high capital costs, very large scales of operation, and considerable technical expertise. In two upper income developing countries, Taiwan and Korea, nuclear power provides over 40 percent of total electricity generation. In other countries, however, there have been some difficulties with nuclear power--e.g., two of India's three operating nuclear plants have suffered high outage rates,[58] and their fourth plant has had construction delays of 7 years.

A number of alternative generation technologies have also been used in developing countries, including cogeneration, geothermal, conversion of solar energy to electricity, wind-driven generators, and the burning of waste material. Although these sources contribute relatively small amounts to total electricity supplies in the developing world, there is strong policy interest in expanding the use of these alternative generating technologies.

The operating efficiencies of electricity generating plants are generally lower in developing countries than in the United States.[59] Although many factors affect power plant efficiency (notably input fuel quality), the use of less efficient, poorly maintained technologies contributes to the low efficiencies of developing world powerplants.

Electricity Transmission and Distribution

Transmission and distribution systems in the developing world have relatively high losses. A recent survey of 76 developing countries found that, in one-half of the countries surveyed, transmission and distribution losses (as a share of total generation) exceeded 15 percent, compared with typical losses of less than 10 percent in the industrialized countries.[60] These losses include both technical losses and unmetered consumption (theft).

[52] IEA, op. cit., footnote 4.

[53] Ibid.

[54] United Nations, op. cit., footnote 24.

[55] Ibid.

[56] These are Argentina, Brazil, India, Mexico, Pakistan, Republic of Korea, South Africa, and Taiwan. United Nations, "Energy Exploration and Development Trends in Developing Countries," Report of the Secretary-General, May 14, 1990.

[57] Argentina, Brazil, China, Cuba, Mexico, India, and Republic of Korea all had nuclear powerplants under Construction in 1989. Ibid.

[58] Tata Energy Research Institute, op. cit., footnote 11.

[59] United Nations Conference on Trade and Development (UNCTAD), *Technology Policy in the Energy Sector: Issues, Scope and Options for Developing Countries*, UNCTAD/TT/90, June 15, 1989.

[60] Ibid.

Institutional Issues

Governments in both the developing and industrialized world generally have taken leading roles in directing the development and operation of the electric power sector; this reflects both the importance of electric power in meeting economic and social objectives and the high cost of electric power systems.

Because electricity is considered an important tool within a broader national development strategy[61], developing countries often subsidize electricity prices. In Pakistan, for example, 60 percent of the cost of electricity is subsidized; in India, the figure is 20 percent.[62] Many countries have subsidies for electricity in selected sectors (e.g., agriculture and residential), reflecting either the political influence of the subsidized sectors or government interest in promoting certain economic or social ends. Although electricity prices nearly doubled between 1980-81 and 1986-87 in India, for example, current prices are still far lower than supply costs for residential and agricultural consumers.[63]

There may be many reasons for subsidizing electricity prices in different sectors. For example, rural electrification is promoted as a means to reduce migration to cities by improving economic opportunities and lifestyles in rural areas. Supporters argue that these subsidies benefit society as a whole and not just rural consumers. Others rogue that there is no conclusive evidence that rural electrification can actually produce this benefit.[64] Rural electrification is also seen as 'a powerful instrument at the disposal of central governments to foster political stability in rural areas," although again the evidence is mixed.[65]

Subsidized electricity prices also allow electricity to compete with subsidized prices for alternative fuels. Similarly, when prices of farm products are controlled and kept artificially low, electricity prices (and the prices of other inputs such as fertilizers) are often subsidized to keep farms operating.[66]

Subsidized electricity can have negative impacts, including contributing to power shortages, since consumers tend to use more subsidized electricity than they would otherwise. Moreover, price subsidies keep power company revenues at levels inadequate for developing additional supplies and even for maintaining existing facilities efficiently. Higher prices, on the other hand, limit supplies to higher income groups, an outcome that may conflict with the social goals of electrification.

Capital spending on electricity systems in the developing world is currently estimated at $50 billion to $60 billion annually.[67] Even at that high level of expenditure, investment is expected to be inadequate to meet demand. The United States Agency for International Development (U.S. AID) has estimated that meeting the growing demand for electricity will require capital investment of around $125 billion per year over the next two decades.[68] This enormous capital mobilization requirement represents a large fraction of both total economic activity and total gross domestic investment in the developing world. The total economic output of all lower- and middle-income countries as measured by GDP was $2,716 billion in 1987, with total gross domestic investment of $662 billion.[69] Much of the capital costs of electricity plants must be paid in foreign exchange,[70] leading to balance of payment problems and compounding the problems of high operating and capital costs in the electric sector.

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[61] United Nations Center for Human Settlements (Habitat), *Guidelines for the Planning of Rural Settlements and Infrastructure: Electrification—A Methodology* (Nairobi, Kenya: United Nations, 1985), p. 43.

[62] U.S. Agency for International Development, Op. cit., footnote 50, p. 26.

[63] A. Faruqui et al., *Application of Demand-Side Management (DSM) to Relieve Electricity Shortages in India*, draft contractor report prepared for the Office of Technology Assessment, April 1990, p. 59.

[64] For a discussion of these issues, see D. Barnes, *Electric Power for Rural Growth* (Boulder, CO: Westview Press, 1987), pp. 109-118.

[65] United Nations Center for Human Settlements (Habitat), op. cit., footnote 61.

[66] Mohan Munasinghe, Rural *Electrification for Development* (Boulder, CO: Westview Press, 1987), p. 247.

[67] U.S. Agency for International Development, op. cit., footnote 50, p. iv.

[68] Ibid., p. 25. A slightly lower estimate ($60 t. $100 billion) from the World Bank is given in A. Churchill and R. Saunders, "Financing Of the Energy Sector in Developing Countries," World Bank, Industry and Energy Departmen(Working Paper Energy Series, Paper No. 14, April 1989.

[69] World Bank, *World Development Report 1989 (New* York, NY: Oxford University Press, 1989), tables 3 and 9.

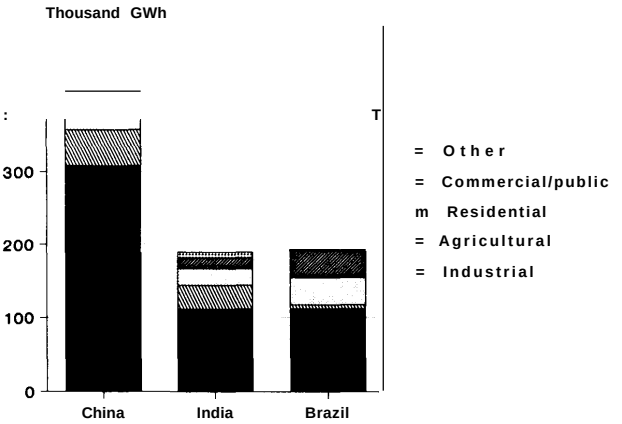
[70] U.S. AID estimates that around 45 percent of capital investment will be in foreign exchange. U.S. Agency for International Development, footnote 50, p. 25.

Even with the enormous financial, technical, and institutional effort targeted to the development of the electricity sector over the past decades, capacity still is often insufficient to provide reliable, high-quality power in developing countries. Outages are common in many countries. For example, Bombay experienced 1,000 outages annually over a recent 5-year period.[71] Even when power is available, voltage fluctuations are often extreme, restricting the use of some types of equipment. The electronic circuits of today's compact fluorescent light bulbs, for example, do not tolerate wide voltage fluctuations;[72] and computer operations are disrupted by outages. As a result, in many countries, poor power quality and lack of reliability undermine the economic benefits of electric power.

Low reliability results in formidable losses in economic productivity. Load shedding in India is estimated to cost the equivalent of 1 to 3 percent of GDP annually.[73] Accurately estimating the productivity lost when existing equipment cannot be operated due to power outages is difficult, and estimating productivity lost as industry forgoes the purchase and use of new electric equipment is even more uncertain; however, the impacts may be quite large.

Ironically, a few developing countries suffer from an excess of electric capacity. For example, it has been estimated that seven East African countries have approximately 7,000 MW of excess generating capacity (i.e., capacity over and above what is needed for reliable system operation) .74 This situation results from the "lumpiness" of electric generating facilities, especially hydropower. Putting a large new generating facility in service before the domestic load can absorb the new supplies results in overcapacity, and ties up scarce capital.[75]

Figure 4-6-Electricity Consumption by Sector in Selected Regions of the Developing World, 1985



SOURCE: International Energy Agency, *World Energy Statistics and Balances* 1971 -1987 (Pans: OECD, 1989).

Electricity Consumption

Industry consumes most of the developing world's electricity (see figure 4-6 and table 4-5). In contrast, electricity use in the United States is divided among the industrial, residential, and public service/commercial sectors (see table 4-5). China, the largest electricity user in the developing world,[76] uses 75 percent of its electricity in industry. Similarly, India and Brazil use over half their electricity in industry. Agriculture uses large amounts of electricity for pumping in India and China, while residential lighting and appliances use large amounts of electricity in Brazil.

Outlook for Improvements

The mix of energy supplies varies widely in the developing world—from China's heavy reliance on coal in the industrial and residential sectors to Brazil's extensive use of hydropower-based electricity. Despite the diversity of sources, however,

[71] Tata Energy Research Institute, *Two Strategies for Electric Load Leveling for India*, Phase I Final Report (New Delhi, India: 1987), p. 6., as cited in J. VanDomelen, *Power to Spare: The WorldBank and Electricity Conservation* (Washington, DC: World Wildlife Fund and Conservation Foundation 1988) p. 4.

[72] Lawrence Berkeley Laboratory, *Energy Technology for Developing Countries: Issues for the U.S. National Energy Strategy*, LBL-28907 (Berkeley, CA: December 1989).

[73] U.S. Agency for International Development, op. cit., footnote 50, p. 21.

[74] I. Hume, "Energy Efficiency in Developing Countries, " in M. Munasinghe and R. Saunders (eds.), *Energy Issues in the Developing World*, World Bank Industry and Energy Department Working Paper, Energy Series Paper No. 1 (Washington DC: World Bank, 1988).

[75] Excess capacity can also lead t. distortions in pricing and demand. For example, the large surplus capacity in Brazil when Itaipu came on-line led the electricity authorities to offer industry exceptionally strong incentives to buy electricity. Electricity was so cheap that it was used by industrial customers virtually as a boiler fuel. Within a few years, however, load growth in other sectors reduced surplus capacity, but the industrial users were by then reluctant to give up the highly favorable rates.

[76] Over one-fourth of the electricity in the developing world is used in China.

Table 4-5-Electricity Consumption by Sector, 1985 (percent)

End-use sector	China	India	Brazil	United States
Industry	75	59	58	33
Agriculture	12	17	3	1
Residential	7	12	20	35
Public service/commercial	5	8	20	31
Railroads	2	2	1	*
Other/unspecified	•	1		0
Total (percent)	100	100	100	100
Total generation (GWh)	410,700	188,500	192,700	2,621,900

• Less than 1 percent.

NOTES: Totals may not add to 100 percent due to rounding. Brazil, China, and India account for 48 percent of developing world electricity consumption.

SOURCES: Tata Energy Research Institute, *TERI Energy Data Directory and Yearbook 1988* (New Delhi, India: 1989); IEA, *World Energy Statistics and Balances 1970/1985* (Paris: OECD, 1987); IEA, *Energy Balances of OECD* Counties 1987- 1988(Pans: OECD, 1990).

several important characteristics of the energy supply sector can be identified:

- The technologies in use are typically older, less efficient, and less sophisticated than comparable technologies in the industrialized countries.
- The electricity sector accounts for a large share of foreign exchange resources. Rapid growth in electricity demand and the high capital requirements of the sector suggest that the gap between needed and available capital for electricity system expansion will widen. Therefore the electricity systems in many countries could continue to be relatively undependable, inefficient, and technologically outdated.
- The public sector plays a dominant role in most aspects of energy supply, with the exception of biomass.

These characteristics of the energy supply sector in the developing world suggest a number of productive opportunities for improving the efficiency of the energy supply system, recognizing that there are wide variations among developing countries, and that many characteristics that appear inefficient or undesirable when viewed from the current perspective of highly developed nations may in fact represent rational choices given prevailing social, economic, and technical conditions.

A number of institutional, technological, and engineering options can be considered for improving the extraction, processing, and conversion of energy supplies. In oil and gas development, for example, options include both the deployment of new technologies, such as horizontal drilling, and the development of innovative financing mechanisms. Options for coal include technologies such as washing and screening, as well as strategies for minemouth electricity generation to relieve pressure on transport systems. Similarly, institutional issues are critical in any discussion of improving the sustainability of biomass resources.

Both developing country governments and international development agencies already pay much attention to opportunities in the electricity sector. Technological opportunities range from industrial cogeneration, to upgrades of transmission and distribution system efficiencies, to the use of more efficient consumer appliances. Institutional opportunities include the contribution of nonutility generators to electricity networks.

Although technology can do much to improve the energy supply sector, other factors also affect its operation: financial issues, such as subsidies for electricity prices or the high cost of natural gas transportation; institutional and management issues, including shortages of trained personnel; and the incentive structure, notably the dominant role played by government in fossil fuel exploration and delivery systems, all strongly influence system operations, management, and decisionmaking in the energy supply sector.