Chapter 2

Energy and Economic Development

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Chapter 2
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Introduction and Summary

This chapter examines the two-way linkage between energy and economic development in developing countries--how the process of economic development impacts energy, and how, in turn, developments in the energy sector can affect economic growth.

In the course of economic development, commercial energy consumption is observed to increase faster than economic activity. There are a number of reasons for this: the growth of mechanized agriculture and manufacturing, the construction of a modem infrastructure, urbanization, increased transportation of goods and services, rapid expansion in ownership of consumer appliances, and the substitution of commercial for traditional fuels. The absolute amount of traditional energy consumed also continues to rise, although its share of total energy consumption falls.

In the years to come, high rates of economic growth will be needed in developing countries to provide their rapidly growing populations with improved living standards. If current trends in energy and economic growth continue, commercial energy consumption in the developing countries could more than double over the next 40 years according to most projections. Supplies of biomass fuels would also need to increase substantially to meet the needs of growing rural populations and the urban poor.

This prospect raises a dilemma. On the one hand, increases in energy supplies on this scale could severely strain financial resources in the developing countries. The energy sector absorbs a large share of available foreign exchange and capital investment. Consequently, energy supply policies have far--reaching impacts on other development priorities. In many developing countries, financial resources may not be adequate to increase commercial energy supplies on the scale projected above.

On the other hand, inability to supply needed energy can frustrate economic and social development. Already in many countries, the unreliability and poor quality of energy supplies lead to major costs to the economy through wasted materials, stoppage of operations, and investment in standby equipment.

Energy prices are a key factor in the development of a country's energy supply infrastructure, through their impacts on the amount of energy used in the economy, the technologies adopted, and, in some cases, the direction of industrial development. Energy prices in developing countries are typically subject to price regulation throughout the distribution chain. The average level of energy prices, particularly in the electricity sector, are reported to be too low in many countries to ensure the sector's financial viability.

Although commercial fuels attract the most policy attention, two-thirds of the developing world's population live in rural areas with low standards of living based on low-resource farming. This population has little access to commercial fuels and relies largely on traditional sources of energy, gathered and consumed locally, and animal and human energy, often used at very low efficiencies. The main form of traditional energy used is wood, an increasingly scarce and unsustainable resource. This imposes a special hardship on those-mainly women and children-responsible for gathering it. Dung and crop wastes, the other forms of energy widely used for cooking when wood is not available, have alternative uses as soil nutrients.

Economic Development and Its Impact on Energy

The pace of economic growth and level of economic activity have major impacts on the energy sector. From 1965 to 1987, for example, the economies of the developing countries grew at an annual average of 5.3 percent, and their consumption of commercial energy grew by just over 6 percent.[1] These energy growth rates were higher than those in the industrial countries over the same period. As a result, the developing countries' share of global commercial energy consumption also rose-from 17

[1]World Bank, *World Development Report 1989* (New York, NY: Oxford University Press, 1989), pp. 167 and 173.

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percent in 1973 to 23 percent in 1987.[2] High rates of economic growth will continue to be needed in the developing world to provide the rapidly growing population with improved living standards.

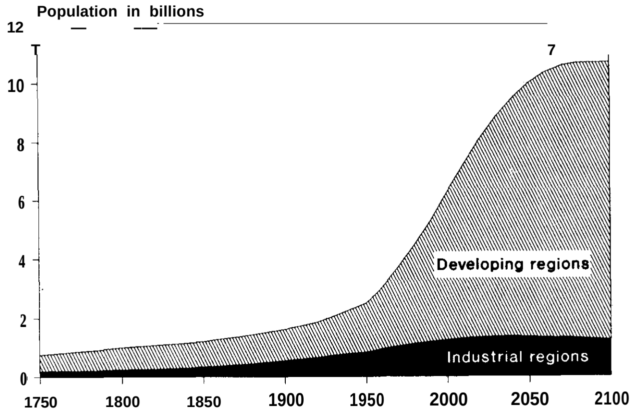
Rising Populations

The past two centuries have witnessed sharply accelerated growth in the global population (see figure 2-l). The largest additions to global population have been in the developing countries and have occurred primarily in the past 50 years (see figure 2-2). Box 2-A discusses factors affecting population growth.

Although current projections of global population growth over the next 35 years differ (see figure 2-3), there is consensus on several major points:

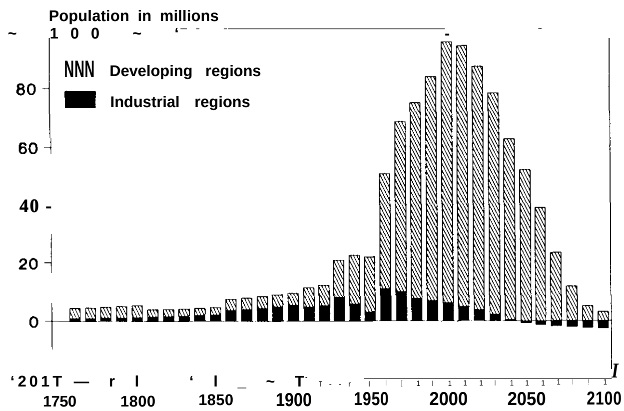
- The world's population is projected to increase despite assumptions of continued declines in fertility rates. The rate of increase in global population, while lower than in the past, still represents a large increase in numbers of people. World Bank estimates,[3] which are similar to both the United Nations medium projection and the U.S. Department of Agriculture projection, project an increase in global population from 5.3 billion in 1990 to 8.4 billion in 2025, an increase of 3.1 billion.
- Virtually all of the increase will come from the developing countries. According to the World Bank projection, for example, population growth in the industrial countries--i.e., nations in the Organization for Economic Cooperation and Development (OECD), the U. S. S. R., and Eastern Europe-is expected to add only about 125 million, or about 4 percent of the global increase (see figure 2-4). The population of the developing countries is estimated to rise from its present level of 4.1 billion to 7.1 billion in 2025, increasing their share of world population from 77 to 88 percent (see figure 2-4).
- Population growth in China is projected to be quite moderate, as current low rates of growth are assumed to be maintained. Projections of China's population growth are critical because of its large share of the global total.
- According to World Bank projections, the biggest increases in population are predicted to come from Africa and Asia, which will account for 30 and 58 percent respectively of the total global increase. In Asia the large addition to population derives from the existing large population base; rates of population growth are relatively low. In Africa, on the other hand, the primary cause is the rapid increase in population that, despite the relatively low population, increases its share of the total population from a current 12 percent to 19 percent in 2025.

Figure 2-1—World Population Growth, 1750-2100 in Industrial and Developing Regions



SOURCE: Thomas Merrick, Population Reference Bureau, "World Population in Transition," *Population Bulletin*, vol. 41, No. 2, April 1986, update based on United Nations 1989 projections.

Figure 2-2—Average Annual Increase in Population Per Decade in Industrial and Developing Regions, 1750-2100

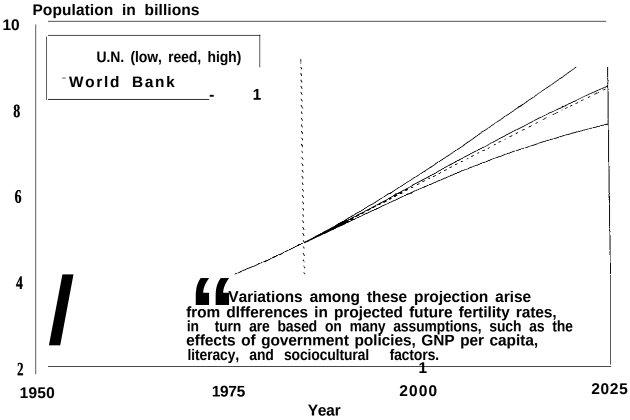


SOURCE: Thomas Merrick, Population Reference Bureau, "World Population in Transition," *Population Bulletin*, vol. 41, No. 2, April 1986, update based on United Nations 1989 projections.

[2] World Energy Conference, *Global Energy Perspective 2000-2020 14th* Congress, Montreal 1989 (Paris: 1989), Table 2.

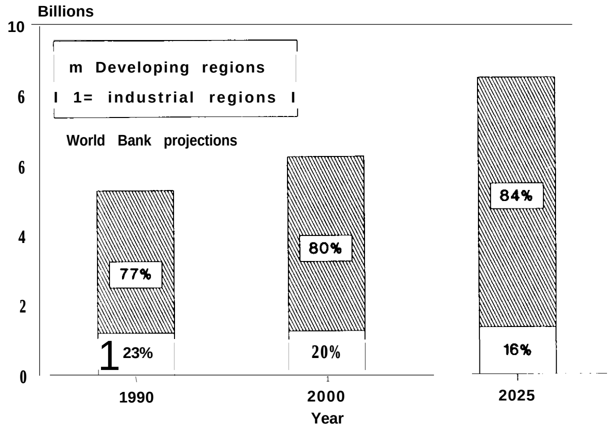
[3] Rodolfo A. Bulatao, Eduard Bos, Patience Stephens, and My T. Vu, *Europe, Middle East, and Africa (EMN) Region Population Projection: 1989-90 Edition*, Population and Human Resources Department, working paper 328 (Washington, DC: World Bank), November 1989, table 5.

Figure 2-3-Historical and Projected Global Population, 1950-2025



SOURCE: Office of Technology Assessment, 1990, based on data in United Nations, *World Population Prospects* 1988 (New York, NY: United Nations, 1989); Rodolfo Bulatao et al., *Europe, Middle East, and Africa (EMN) Region Population Projections, 1989-90 Edition,* World Bank, Population and Human Resources Department, Washington, DC, working paper series 328, November 1989.

Figure 2-4-Projected Shares of Global Population, 2000 and 2025



SOURCE: Rodolfo Bulatao et al., *Europe, Middle East, and Africa (EMN) Region Population Projections, 1989-90 Edition, World* Bank, Population and Human Resources Department, Washington, DC, working paper series 328, November 1989.

Though there will no doubt be some unforeseen divergence from these population paths (changes in fertility rates are difficult to predict; the impact of the AIDS epidemic in Africa on fertility rates and population growth is unknown), it is clear that there will be a large increase in the world's population in the decades ahead, accompanied by a powerful upward pressure on energy consumption. Even with no increase in per-capita energy consumption, the predicted rise in the global population by 2025 implies a 75 percent increase in total commercial energy consumption.

Higher Living Standards

The major development challenge is to provide higher standards of living for the rapidly rising populations of the developing world. This task is all the more urgent because of the declining levels of per-capita income in many of the countries of Latin America and Africa in recent years. Given the projected rise in developing country populations—an annual average of about 1.6 percent over the next 35 yearn-a rise in average per-capita incomes of, say, 3 percent per year implies economic growth rates of around 4.6 percent annually.[4]

It may not be easy to achieve such rates of growth. The current indebtedness of many developing nations has added to the already difficult tasks of economic management, and threatens to jeopardize prospects of attaining even modest improvements in standards of living. The foreign debt of developing countries increased rapidly in the 1970s and 1980s and in early 1989 was estimated at about $1.3 trillion.[5] As a result of this increase and the rise in interest rates, debt service as a share of total exports of goods and services is now double what it was in the early 1970s.[6]

Changes in Energy Consumption With Economic Development

The economic expansion necessary to achieve higher standards of living for the increasing population of the developing world would be expected to

[4]The World Energy Conference ''moderate'' growth rate projection is based on annual economic growth rates of 4.4 percent. Average economic growthrates of 5.3 percent annually are assumed in the series of projections in Alan S. Marine and Leo Schrattenholzer, "InternationalE nergyWorkshop: Overview of Poll Responses,' Stanford University International Energy Project, California, July 1989. The Intergovernmental Panel on Climate Change, "Appendix Report of the Expert Group on Emissions Scenarios (Response Strategies Working Group Steering Committee, Task A)," April 1990, assumes high economic growth rates for the different developing regions of 4 to 5 percent annually, and 2.2 to 3.0 percent annually for the low-growth case.

[5]United Nations Development Programme, *Human Development Report 1990 (New* York, NY: Oxford University Press, 1990), p. 79.

[6]These principal and interest repayments are now much higher than new disbursements of long-term debt to developing countries. The net transfer or outflow of resources from the developing countries amounted to $38 billion in 1987, compared with a net inflow of $35 billion in 1981. See World Bank, *World Development Report 1989* (Washington DC: Oxford University Press, 1989), p. 18.

Box 2-A—Factors Affecting Population Increase

Rates of population growth are determined by the balance between birth and death rates. Historically, death rates were the first to decline, due to improvements in nutrition and sanitation, and medical advances such as vaccines. If death rates decline, but birth rates remain the same, population increases. This is what happened in the presently developed world from 1750 to about 1900. Around that time, however, birth rates started to fall, resulting in an overall reduction in the rate of population increase. This process, the lagged adjustment of birth rates to the prior decline in death rates, is known as the "demographic transition. " In the developing world, the demographic transition is far from complete: death rates have fallen dramatically--though they are still higher than in the industrial countries-but birth rates remain high, leading to a continued rapid rate of increase in total population.[1]

Future trends in population will similarly depend on the balance between death and birth rates. For the developing countries, opportunities still exist to reduce death rates through improvements in medicine and public health, and further declines are likely and desirable. On the side of birth rates, there is much greater uncertainty over future trends. Birth rates are falling in the developing countries, from 41 crude births per thousand population in the mid-1960s to 30 per thousand at present. Birth rates in the developing countries, however, are still well above death rates, and more than twice the birth rates in the industrial countries (currently 13 per thousand).

The number of births depends on three factors: fertility rates, the age structure of the population, and the size of the population base.

The fertility rate is defined as "the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children at each age in accordance with prevailing age-specific fertility rates." Fertility rates in developing countries have fallen steadily, and in some cases sharply, in recent years. For the developing countries as a whole, they fell from 6.1 in 1%5 to 4 in 1987, with particularly sharp declines in China and India, Sri Lanka, Korea, and several Latin American countries. Despite this drop, they are still much higher than in the industrial countries. There are, however, exceptions to this declining trend; fertility rates have not changed in sub-Saharan African countries, and in some of these countries the rates appear to have risen.

Fertility rates are projected to continue declining until the end of the century, when they would be 3.3 compared with the current 4. While this assumption seems reasonable in the light of historical trends, the determinants of family size are not clearly known, and there is inevitably some degree of uncertainty over such assumptions. Broadly speaking, fertility rates decline as levels of economic and social development and urbanization rise, women's education improves, and knowledge about family planning spreads. The connections between these factors are not well-established, however, as they are highly correlated, and it is therefore difficult to disentangle the impact of any single determinant. A higher share of the population living in urban areas, other things equal, maybe of particular importance in lowering fertility rates. In rural farming communities, many benefits accrue to a large family. Children provide farm Iabor—from an early age children are able to perform simple farm chores. Children can also provide, in the absence of social insurance, some guarantee of old age security for parents. These benefits of a large family are not so evident in the urban context, where they may also be outweighed by the financial costs of supporting a large family.

Other factors also influence fertility rates. Cultural and religious factors can lead to higher family size than would otherwise be predicted by indicators of social and economic development and urbanization. Algeria, Libya, Iran, and Iraq, for example, have fertility rates near or over 6 despite their relatively high per-capita incomes. On the other hand, aggressive government policies to restrict families can lead to lower family sizes than predicted by other social and economic indicators. For example, fertility rates in China, a low-income country, fell dramatically from 6 in the mid-1960s to 2.4 in 1987—lower than the rate for the industrial countries 20 years ago-due largely to strong government policy.

With a given fertility rate, the number of births will be higher if a larger share of the population is in the reproductive age group. In the developing countries, young people comprise a higher share of the population. This population structure gives a much greater "population momentum" (the tendency for population growth to continue even after fertility rates have fallen to the replacement level). In the developing countries, the rising share of women of childbearing age in the population will continue to exert strong upward pressure on the population, despite the expected drop in fertility rates.

The size of the population base is the third determinant of population growth. The highest fertility rates exist in the developing countries, which already have by far the largest share (77 percent) of the global population. This means that larger numbers are being added to the world population than would be the case if the high fertility rates applied to the industrial countries, which comprise only 15 percent of the global population.

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[1] World Bank, *World Development Report 1989* (New York, NY: Oxford University Press, 1989), pp. 164-165.

lead to comparable increases in energy consumption. In addition, several factors inherent in the development process tend to cause commercial energy use in developing countries to rise more rapidly than the gross national product.

First, most of the people in developing countries now rely primarily on traditional biomass fuels—wood, crop wastes, animal dung-for their energy needs. These fuels are often difficult and time-consuming to gather, are inefficient and awkward to use, and can cause significant environmental damage. Similarly, most people in developing countries rely primarily on human and animal muscle power for doing their work, despite its low efficiency and limited output. People who are dependent on these traditional forms of energy will turn to commercial fuels and technologies if and when they are available and affordable. Thus, the share of traditional fuels in total energy consumption falls sharply as development proceeds. In the low-income African countries, traditional fuels account for as much as 90 percent of total energy use. In the middle-income developing countries their share falls typically to under 20 percent.

Second, most developing countries are now building their commercial, industrial, and transportation infrastructures. This requires large quantities of energy-intensive materials such as steel and cement. As a result, energy use in the near- to mid-term increases faster than income.

Third, developing countries are experiencing rapid urbanization. Urbanization has profound effects on the amount and type of energy consumed.[7] As industry and the labor force become more concentrated in urban areas, transportation needs grow. Food and raw materials are hauled longer distances, and finished products are marketed over a wider area. Urban households purchase a larger share of their total needs from outside the family, compared with rural households, and commercial providers of goods and services are more likely to use modern fuels. Scarcity of space in cities encourages the substitution of modern, compact energy forms for the bulkier biomass fuels. Finally, the growing food needs of the cities encourage changes in agricultural technology, which usually involve increased use of modern fuels and energy-intensive fertilizers.

Fourth, modern manufacturing technologies and materials have significantly lowered the real cost of many consumer goods--from radios to refrigerators-compared with costs a generation ago, and global distribution systems have increased their accessibility. People in developing countries can thus purchase many consumer goods at a far earlier point in the development cycle than did people in today's industrial countries. This could increase energy use in the near- to mid-term both to produce the materials for consumer goods and—particularly for those that are intensive energy users, such as motorcycles, cars, air conditioners, and refrigerators—to operate them.

On the other hand, there are factors that may counterbalance these trends and significantly moderate the rapid increase in energy demand.

First, the high cost of developing national energy infrastructures and of purchasing energy to support growing energy demands could potentially sharply limit economic growth. This possibility is highly undesirable given current low, and in many cases declining, living standards in developing countries.

Second, the expected growth in energy use in developing countries could be reduced through efficiency improvements. Energy is now used much less efficiently in developing countries than in industrial countries. Traditional fuels and technologies are often much less efficient than modern ones: for example, the efficiency of a typical wood-fueled cooking stove is just one-fourth that of a modern gas range. Moreover, the efficiency of energy use in the

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[7] Donald W. Jones, "Urbanization and Energy Use in Energy Development" *Energy Journal*, vol. 10, No. 4, October 1989.

modern sector in developing countries is often far lower than that commonly achieved in the industrial countries. If developing countries adopt the most efficient technologies now available, they might achieve average energy efficiencies that are higher than those in industrial countries that have a large installed base of older and less efficient infrastructure and equipment.

Third, continued economic development is at some point accompanied by structural changes that shift investment from energy-intensive infrastructure (roads, buildings, etc.) to consumer goods (refrigerators, cars, etc.) and finally to less material-intensive but higher value-added goods such as personal services and electronics.

Energy use in developing countries will depend on the net impact of these opposing factors. At low levels of development the first set of factors predominates, and commercial energy consumption typically rises much faster than gross domestic product (GDP). Figure 2-5 compares per-capita commercial energy consumption with per-capita GDP for selected countries, ranging from lowest to highest income.[8] As this figure suggests, within the poorest countries commercial energy consumption rises faster than per-capita GNP; in the middle-income countries they rise at about the same rate; and at the highest levels of income, the increase in total commercial energy consumption is less than the increase in per-capita GNP.

It is often argued[9] that GNP per capita, a measure of the value of economic output in relation to population size, is an inadequate and misleading indicator of standards of living and well-being.[10] An index recently developed by the United Nations Development Programme, the Human Development Index (HDI),[11] incorporates both economic and social factors. This index is based on three indicators: life expectancy at birth, adult literacy, and per-capita purchasing power.[12] The first two are sensitive to social conditions in a country and in addition reflect underlying conditions of income distribution. Average purchasing power in a country gives some indication of material standards of living. At low values, the HDI also shows a close positive association with commercial energy consumption (see figure 2-6). Higher levels of HDI, however, can be achieved with a wide range of commercial energy consumption.

Commercial energy is only part (and for the poorest countries, a very small part) of total energy consumption. If estimates of traditional fuel consumption are included with commercial fuel to represent total energy consumption, the association between per-capita energy consumption and GNP remains close, but at lower income levels the slope is less steep than in figure 2-5.[13] Adding commercial and traditional energy together to make total energy consumption does not, however, take into account the lower conversion efficiencies of traditional energy compared with commercial energy. If traditional energy consumption were expressed in com-

[8] The relationship between GDP per capita and commercial energy consumption shown in figure 2-5 is consistent with other studies. A per-capita income elasticity for fossil fuels of about 1.5 is given for 13 industrial and developing countries in Gerald Leach et al.,*Energy and Growth* (London: Butterworths, 1986),p. 25. That is,a given increase in per-capita GNP between countries(purchasing power parity) is associated with a 50 percent higher increase in consumption of fossil fuels. Another study, based on 100 countries, reports a per-capita income elasticity of 1.26 (i.e., a given increase in per-capita GNP between countries is associated with a 26 percent higher increase in commercial energy consumption). See B.W. Ang, "A Cross-Sectional Analysis of Energy Output Correlation" *Energy Economics* (London: Butterworths, 1987), table 3, p. 280. This elasticity is based on market exchange rates; comparison of purchasing power parity GNP data increases the elasticity to 1.8. These elasticities are based on cross-sectional studies (i.e., intercountry comparison at a given point in time, rather than developments in an individual country over time), which are considered to give a more accurate picture of the long-term relationship between energy consumption and economic growth.

[9] For example, see Carlos Andrea Perez, *Towards a New Way to Measure Development (Caracas,* Venezuela: Office of the South Commission in Venezuela, 1989).

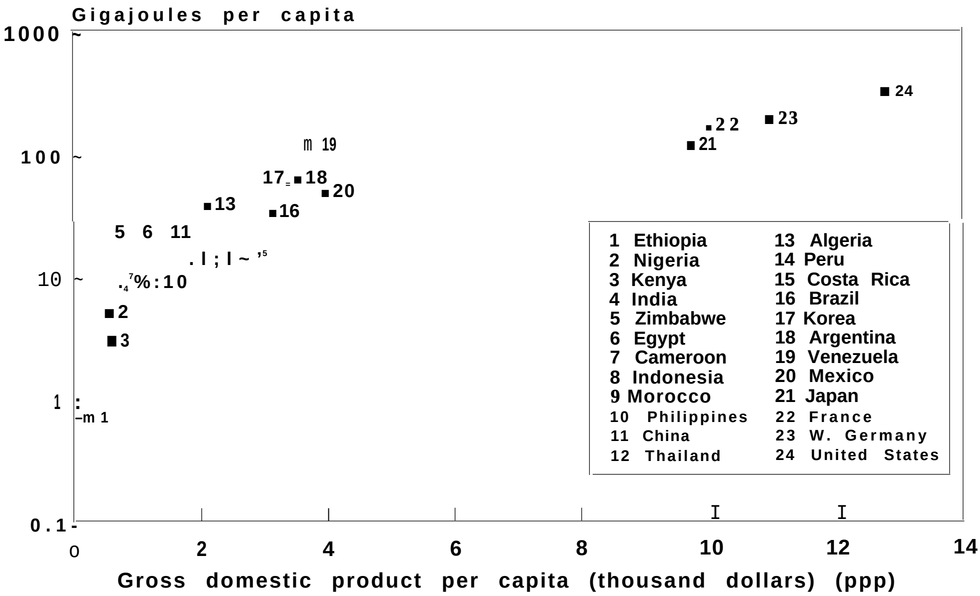
[10] GNP may be an inadequate measure of social well-being, but it nonetheless correlates strongly with many social indicators. See Partha Dasgupta, "Wellbeing and the Extent of Its Realization in Poor Countries," *The Economic Journal,* supplement (Cambridge, MA: Royal Economic Society Basil Blackwell, 1990), pp. 1-32. The argument is made here that GNP per capita also correlates closely with political and civil rights.

[11] United Nations Development Programme, *Human Development Report 1990,* op. Cit., footnote 6, pp. 11-16.

[12] The values of achievement for these indicators were Japan's life expectancy at birth of 78, an adult literacy rate of 100 percent, and the average official "poverty Une" income in nine industrial countries, adjusted to take into account purchasing power, of $4,861 per capita

[13] Leach, op. cit., footnote 9, p. 25, gives per-capita income elasticities for total energy at about 1.2, lower than the 1.5 for fossil fuels alone. B.W. Ang, "A Cross Sectional Analysis of Energy Output Correlation" op. cit., footnote 9, reports income elasticities of traditional energy consumption of -0.95 (i.e., a 10 percent increase in GNP per capita is associated with a 9.5 percent *decline in traditional* energy consumption) and for total energy consumption (commercial and traditional) of 1.05.

Figure 2-5-Commercial Energy Consumption and Economic Development in Selected Countries



SOURCES: United Nations, 1986 Energy Statistics Yearbook(New York, NY: United Nations, 1988), table 4; Robert Summers et al., "A New Set of International Comparisons of Real Product and Price Levels, Estimates for 130 Countries, 1950-1985," *Review of Income and Wealth, Series* 34, No. 1, March 1988.

mercial fuel equivalent,[14] the increase in energy consumption in relation to GNP might be somewhat greater than the increase in total energy (an energy elasticity of just over 1.0), but less than the increase in commercial energy alone (1.5 or more).

The inclusion of traditional energy, though necessary to provide a more complete picture of the relationship between economic growth, social development, and energy use, raises problems of its own. First, the measurement of traditional fuels is difficult and prone to underestimation. For example, for Indonesia, Malaysia, the Philippines, and Thailand, estimates by the United Nations Food and Agricultural Organization, the Asian Development Bank, and the World Energy Conference-three frequently quoted sources of data on traditional fuels-are found in almost all cases to be considerably lower than in other cou.ntry-specific studies.[15]

Second, when considering traditional sources of energy, it is difficult to know whereto draw the line. Animate forms of energy are important in most developing countries, particularly the poorest. If the biomass fed to bullocks to provide plowing and irrigation services were included, the amount of traditional energy consumed would increase substantially. Further, if the large amounts of biomass burned in preparing soil for cultivation in slash and burn agriculture were included, per-capita energy use where shifting agriculture is practiced could conceivably be as high or higher than in the industrial countries.[16]

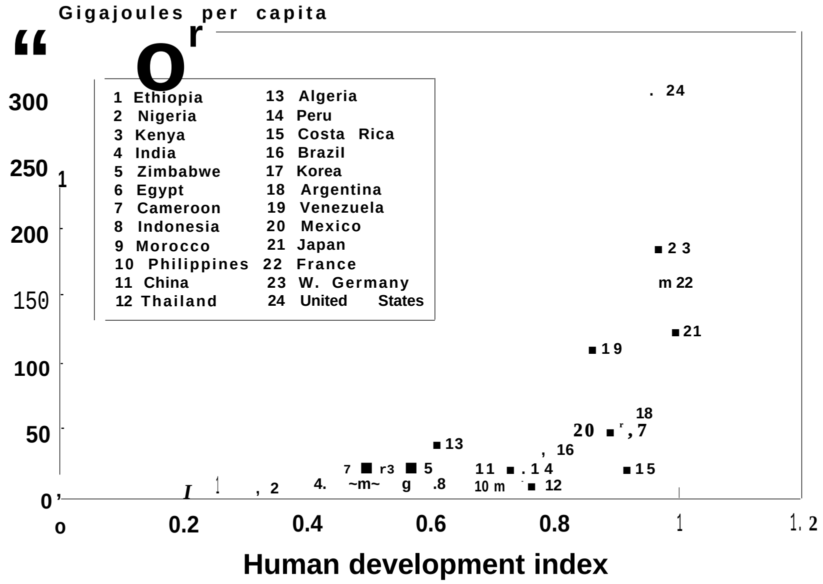
Although GNP growth is an important determinant of energy consumption, it is not the only one. Table 2-1 shows commercial and total energy consumption relative to GNP for different levels of income. If the amount of energy consumed were tied to the level of output or development, the energy intensities of all countries would be the same. As these figures show, however, there are considerable variations in energy intensity (the ratio of energy consumption to GNP) at all levels of development. Among the industrial countries, energy intensities vary widely. And among the developing countries, energy intensities of countries with the same level of

[14] B.W. Ang, "A Method for Estimating Non-commercial Energy Consumption in the Household Sector of Developing Countries," *Energy* (London: Pergamon Press, 1986), p. 423, table 8.

15&, op. cit., footnote 15, P. 423, table 8.

[16] See Kirk R. Smith, "The Biofuel Transition," *Pacific and Asian Journal of Energy*, vol. 1, No. 1, January 1987, p. 18, figure 5.

Figure 2-6—Commercial Energy Consumption and Social Development in Selected Countries



SOURCES: United Nations, 1986 Energy Statistics Yearbook(New York, NY: United Nations, 1988), table 4; United Nations Development Programme, *Human Development Report 1990 (New York, NY:* Oxford University Press, 1990), p. 79.

Table 2-l—Energy Intensities in Selected Countries

Country	Gross domestic product, 1985	Total energy consumption per GDP		Commercial energy consumption per GDP	
	$PPP[a]	GJ/$1,000	Index, U.S.= 100	GJ/$1,000	Index, U.S.=1OO
Ethiopia	304	29.6	123	2.3	10
Nigeria	565	24.8	103	9.0	38
Kenya	603	29.9	124	5.0	21
India	775	15.5	64	11.4	48
Zimbabwe	954	30.4	126	22.3	94
Egypt	1,080	21.3	88	20.6	87
Cameroon	1,180	16.9	70	9.1	38
Indonesia	1,269	12.6	52	6.6	28
Morocco	1,284	7.8	32	7.3	31
Philippines	1,352	11.1	46	6.7	28
China	1,489	15.4	64	14.3	60
Thailand	1,896	12.7	53	7.0	29
Algeria	2,133	17.8	74	17.4	73
Peru	2,333	9.9	41	8.1	34
Costa Rica	2,712	16.2	67	8.3	35
Brazil	3,164	16.4	68	10.7	45
Korea	3,381	16.6	69	16.1	68
Argentina	3,640	17.0	71	15.9	67
Venezuela	3,723	29.8	124	29.9	126
Mexico	3,987	13.3	55	12.5	53
Japan	9,739	12.7	53	12.7	54
France	10,032	16.1	67	16.0	67
Germany	10,959	17.0	70	16.9	71
United States	12,787	24.1	100	23.7	100

a ppp refers to purchasing power Parity.

SOURCES: United Nations, 1986 Energy *Statistics* Yearbook (New York, NY: United Nations, 1988), table 4 for energy consumption data. Robert Summers et al., "A New Set of International Comparisons of Real Product and Price Levels, Estimates for 130 Countries, 1950-1985," *Review of Income and Wealth,* Series 34, No. 1, March 1988 for gross domestic product, purchasing power parity.

development (measuredly GNP per capita) can vary more than fourfold.[17]

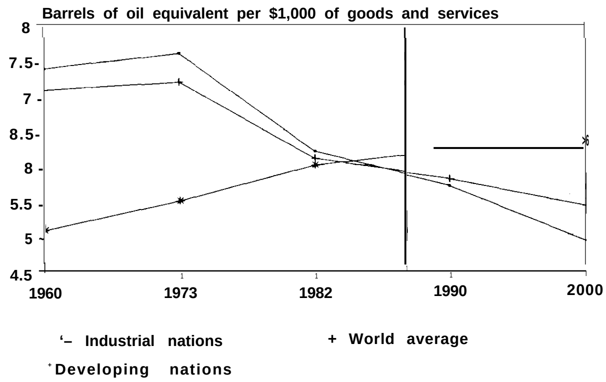
Variations in energy intensity are also evident in individual countries or groups of countries over time, as shown in figure 2-7. In the years immediately before 1973, global energy intensities rose. After 1973, there was a sharp drop in the industrial countries, in contrast to a continued rise in the developing nations, if at a lower pace. Experience within the developing countries varied considerably, again testifying to the importance of factors other than economic growth in determining energy consumption.

Differences in rates of urbanization and industrial structure account for part of the variation in energy intensities. Countries with a large share of energy-intensive industries, such as steel, paper, chemicals, and aluminum, will tend to have higher energy intensities than countries with few energy-intensive industries. Nigeria, Egypt, Algeria, and Venezuela (with large oil drilling and refinery operations) and Argentina, Korea, Zimbabwe, and China (with large metals industries, mainly iron and steel) all have relatively high energy intensities.

The impact of changes in industrial mix is also evident over time. About half of the post-1979 decline in energy intensity in China (which fell by 40 percent between the late 1970s and the late 1980s) can be ascribed to the limits on the expansion of heavy industries and to the promotion of light, and often export-oriented, manufactures (e.g., textiles, consumer electronics, processed foodstuffs, and plastics) .18 The equally dramatic decline in Korea's energy intensity is also due in large part to the changing industrial mix. Although the output of heavy industries in Korea rose sharply in these years, production of less energy-intensive industries such as machinery and transport equipment grew even more rapidly, resulting in a declining share of heavy industry in the total.

Energy intensities are also influenced by the technologies used throughout the economy. For example, the older generation of coal-burning technologies still used in developing countries are much less efficient than modern technologies. Consequently, the coal-burning countries (India and China) are more energy-intensive than countries largely reliant on oil and gas.

Figure 2-7—Energy Intensity and Economic Development, 1960-2000



SOURCE: World Bank, Industry and Energy Department, "Energy Issues in the Developing World," Energy Series Paper No. 1, February 19s8.

Some of the factors that determine energy consumption (e.g., the size of the country and the location of natural resources in relation to industry and major markets) are country-specific, but others can be affected by policy decisions.

Projected Energy Consumption in Developing Countries

In the past, the three factors discussed in the preceding section—rapidly rising population, high economic growth rates to provide improved standards of living, and structural change as development gets underway-have been associated with rapid rates of increase in commercial energy consumption in developing countries. If these trends continue, increases in commercial energy consumption in developing countries could be very large. Table 2-2 illustrates some of the current projections. The synthesis of a wide range of projections shown in this table suggests that commercial energy consumption in the developing world (including here OPEC) in 2010 could be 2.5 times higher than it was in the base year, 1985, an annual rate of increase of

[17]From the limited sample shown in table 2.1, there does not appear to be a systematic tendency for energy/GNP ratios to rise as levels of development rise; the energy/GNP ratios of the advanced developing countries are very similar to those of Europe and Japan. However, Ang, op. cit., footnote 9, using a wider sample, shows a commercial energy/GNP ratio with respect to GNP per capita at 0.80. That is, a 10 percent increase in GNP is associated with an 8 percent increase in the energy/GNP ratio.

[18]Vaclav Smil, ''China's Energy: A Case Study, " contractor report prepared for the Office of TechnologyAssessment, April 1990.

3.8 percent. China accounts for more than one-third of the projected increase.

The World Energy Conference forecasts a somewhat slower rate of growth in commercial energy consumption in the developing world, an annual average increase of 3.3 percent. By 2020, however, consumption of commercial energy in the developing world would be three times higher than in 1985, and consumption of traditional fuels about 25 percent higher (see figure 2-8). Population growth and rising standards of living each account for about half of the total increase.[19]

The Energy Sector and the Macroeconomy

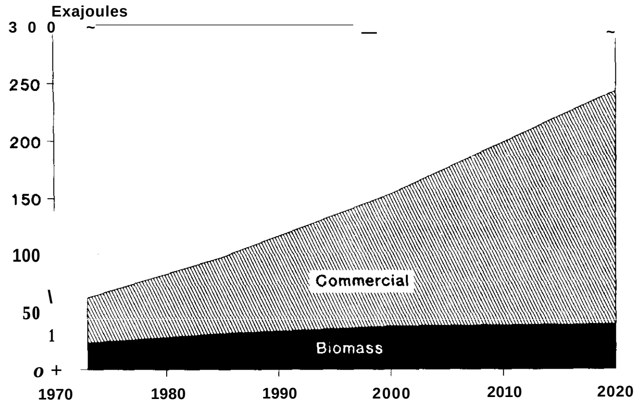
Energy is widely recognized as a key economic sector in developing countries. Reliable and affordable supplies of energy make major contributions to economic and social development; conversely, inadequate or unreliable energy supplies frustrate the development process.

Financing Energy Supplies

Most developing countries (59 out of 80) are net energy importers, relying on imports for virtually all domestic commercial energy consumption; for many countries, oil imports represent 30 percent or more of total export earnings.[20] The share of energy imports in the total export earnings of developing countries has fluctuated widely in recent years as oil prices have changed. Such wide fluctuations are highly disruptive to energy planning and economic development.

Many developing countries emphasize domestic production of energy. Investments in highly capital-intensive energy supply systems often represent a major share of the total investment budget (see table 2-3), accounting in some countries for over 40 percent of all public investment.[21] As the predominant claimant on scarce capital resources, developments in the energy sector therefore have a major impact on the amounts of investment available for other economic and social development.

Figure 2-8-Historical and Projected Energy Consumption in Developing Countries: World Energy Conference "Moderate" Projections



SOURCE: World Energy Conference, Conservation and Studies Committee, Global Energy *Perspective* 2000-2020, 14th congress, Montreal 1989 (Paris: 1989).

The scale of future investment demands for the energy sector in developing countries is projected to be very large. The World Bank, for example, estimates that investments of $125 billion annually (twice the current level) would be needed in developing countries to provide adequate supplies of electricity.[22] According to a World Bank estimate of annual average expenditures on commercial energy supply facilities for developing countries, electricity accounts probably for one-half of the total; oil, including refineries, accounts for about 40 percent; and natural gas and coal 5 percent each. These expenditures do not include investment in small-scale renewable or energy conservation.

[19] The Intergovernmental Panel on Climate Change has undertaken projections of energy consumption in developing countries in "Appendix Report of the Expert Group on Emissions Scenarios (Response Strategies Working Group Steering Committee, Task A)," April 1990. Several scenarios are provided, with different rates of economic grow@ emission coefficients, and policies. The high economic growth (growth rates similar to the other studies quoted here), low emissions scenario forecasts a threefold increase in developing world energy consumption between 1985 and 2025, which is reasonably similar to the World Energy Conference forecast. The high growth, high emissions scenario is similar to the combined forecast results in Alan S. Marine and Leo Schrattenholzer, *International Energy Workshop: Overview of Poll Responses (Palo* Alto, CA: Stanford University, International Energy Project, July 1989).

[20] Energy imports and debt service together account for over one-third of total export earnings in middle-income countries, and almost 40 percent in lower-income countries (excluding China and India).

[21] These &@ cover investments in the energy sector by public entities. They may include some small amounts of investment in energy conservation, but virtually all is in energy supplies. They do not include private investment in backup equipment.

[22] World Bank, "Capital Expenditure for Electric Power in the Developing Countries in the 1990' s," World Bank Industry and Energy Department Working Paper, Energy Series Paper No. 21, Washington DC, February 1990.

Table 2-2--Commerciai Energy Consumption, 1985 and Projections for 2010 (EJ=Exajoules)

	1985 (EJ)	Share of total percent	2010 (EJ)	Share of total percent	AARG,[a] 1985-2010 percent	Increase in consumption, 1985-2010 (EJ)	Share of increase percent
Developing countries	69.26	23.3	175.!56	34.5	3.8	106.30	50.2
China	21.91	7.4	59.54	11.7	4.1	37.63	17.8
OPEC	11.65	3.9	28.91	5.7	2.5	17.26	8.1
Non-OPEC developing countries	35.70	12.0	87.11	17.1	3.6	51.41	24.3
OECD	155.83	52.4	215.03	42.2	1.3	59.20	27.9
United States	73.87	24.8	98.47	19.3	1.2	24.60	11.6
U.S.S.R. and Eastern Europe	72.32	24.3	118.66	23.3	2.0	46.34	21.9
Total	297.41	100.0	509.25	100.0	2.3	211.85	100.0

[a]AARG = annual average rate of growth.

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

Table 2-3-Estimated Annual Energy investment as a Percentage of Annual Total Public investment During the Early 1980s

Over 40 percent	30-40 percent	20-30 percent	10-20 percent	0-10 percent
Argentina	Ecuador	Botswana	Benin	Ethiopia
Brazil	India	China	Egypt	
Colombia	Pakistan	Costa Rica	Ghana	
Korea	Philippines	Liberia	Jamaica	
Mexico	Turkey	Nepal	Morocco	
			Nigeria	
			Sudan	

SOURCE: Mohan Munasinghe, *Electric Power Economics* (London: Butterworths, 1990), p. 5.

About one-half of total estimated energy supply investments are projected to be in foreign exchange.[23] The foreign exchange component for oil and gas is typically high (about two-thirds of the total), as much of the equipment must be imported. On the other hand, foreign exchange costs for coal development are low (about one-quarter of the total), mainly because the major coal-using countries, India and China, manufacture coal industry equipment domestically. The projected share of foreign exchange in electric power varies widely according to country. In countries with developed industrial sectors, the share may be between 5 and 10 percent, but in countries that import all their generating equipment, the share rises as high as 70 Percent.[24]

Achieving these high levels of foreign resources for the energy sector investment poses immense challenges. Though most countries are likely to experience difficulties, the issues will vary from country to country. The poorest countries are highly dependent on confessional aid (which accounted for 80 percent of their total external borrowing for the energy sector in 1975-80). Their success in acquiring funds will depend on the extent of the increase in confessional flows. On the other hand, the middle-income countries depend mainly (80 percent) on export-related and private financial flows for their external financing of energy investments. The situation is particularly acute in highly indebted developing countries.

The other half of the projected increase in investment in the energy sector comes from domestic resources, with a particularly high share in electricity and coal. In many countries, however, the financial situation of the power sector has deteriorated, as increases in costs have not been matched by

[23]External funding for the energy sector was projected to come largely (almost three-quarters) from private sources (supplier credit and private commercial loans). Loans from multilateral agencies and bilateral aid accounted for about one-quarter.

[24]World Bank, The *Energy Transition in Developing Countries* (Washington, DC: 1983).

increased revenues.[25] The financial viability of oil refinery operations in many countries is also compromised by the structure of petroleum product prices.[26] The issue of domestic resource mobilization is of particular importance for coal, where much of the financial resources needed are local rather than foreign.

There are indications that the developing countries are paying increased attention to resource mobilization for the energy sector. Several countries (e.g., Peru, Ecuador, and Colombia) are currently opening more of their territories to oil exploration by foreign firms. Requirements for government participation in oil development ventures are being relaxed. Improved fiscal arrangements providing for the special characteristics of gas have been adopted in Egypt, Tunisia, Pakistan, and elsewhere with a dramatic increase in exploration specifically directed at gas.[27]

Energy Supply Reliability

Just as the presence of reliable supplies of high-quality energy can be a strong incentive to economic development, so unreliable supplies can discourage development and add substantially to the cost of usable power. Electricity supplies in many developing countries are characterized by frequent service curtailments to customers, including blackouts, brownouts, and sharp power surges. This can have two types of impacts:

- Industries and offices are unable to operate, production is lowered, and raw materials are wasted. In China, for example, it is claimed that electricity shortages and disruptions during the 1980's were responsible for idling at least 20 percent of the country's industrial capacity.[28] For the five public-sector steel plants in India, it has been estimated that at 1986-87 operating levels, irregular and restricted electricity supply resulted in increased electricity consumption of over 216 gigawatthours at a cost of $10 million, and the poor quality of the electricity resulted in additional consumption of 412 gigawatthours at a cost of $18 million.[29] More generally, lost industrial output caused by shortages of electricity in India and Pakistanis estimated to have reduced GDP by about 1.5 to 2 percent.[30] Residential consumers are also affected.
- Many consumers, both residential and industrial, are obliged to invest in a variety of equipment-voltage boosters, standby generators, storage batteries, kerosene lamps-in order to minimize the impact of disrupted supplies. Though no data are available, expenditures on these devices are certainly substantial, adding to the cost of providing usable supplies.

Such supply constraints are usually associated with electricity, but there are also shortages of other sources of energy. Supplies of household fuels in many countries (e.g., India) are notoriously intermittent. This accounts for the existence of a wide range of cooking systems in many households in order to ensure against the shortage of any one fuel. Transportation services are also subject to disruption because of unreliable fuel supplies.

Energy Pricing and Demand Management

Energy prices play a key role in energy sector development, through their impacts on the amount of energy used in an economy, the technologies adopted, and in some cases, the direction of industrial development. The effects on the energy infrastructure are long term in nature, and often difficult to reverse.

Energy pricing policy may have several objectives: efficient allocation of resources, provision of affordable supplies to consumers, reasonable returns to energy producers, substitution between fuels for

25World Bank, "Review of World Bank Lending for Electric power," World Bank Industry and Energy Department Working Paper Energy Series, Paper No. 2, March 1988.

26Donald Hertzmark, "Energy Efficiency and Energy pricing in Developing Countries," contractor report prepared for the Office of Technology Assessment, May 1990.

27Theodore J. Gorton, "Petroleum in the Developing World," contractor report prepared for the Office of Technology Assessment, July 1990.

28Vaclav Smil, "China's Energy: A Case Study," op. cit., footnote 18.

29Energy and Environmental Analysis, "Conserving Process Heat in Primary Industries of India and China," contractor report prepared for the Office of Technology Assessment, April 1990.

30Arun P. Sanghvi, "Impacts of Power Supply Inadequacy in Developing Countries," *Journal of Energy Policy* (forthcoming).

national security or environmental reasons, promotion of regional development and industrial competitiveness.[31] The weights of these different objectives in the formulation of energy policy vary among countries. The importance of the regional development objective, for example, varies from country to country depending on geographical configuration, politics, and history. As in other aspects of economic and social policy, however, there are several characteristics of energy pricing that are shared by many of the developing countries:

- Governments play a strong role in the commercial energy sector. In virtually all developing countries the electricity sector is government owned, and in many countries the government also owns the coal, and oil and gas sectors. Regardless of the form of ownership, the government typically regulates prices of energy products, frequently at several levels of the production and distribution chain.
- Social objectives are an important factor in formulating energy pricing policies. As a basic necessity of life, energy accounts for a substantial part of total household expenditures. Governments frequently aim to keep the typical cost of household fuels-e. g., kerosene for lighting and cooking, and in some cases electricity-low. The large number of poor in the population also makes price stability an important policy objective. Though social equity issues are a major preoccupation in the pricing of commercial fuels, prices of the most common form of energy used by the poor—wood and charcoal-are usually not regulated.
- Economic objectives, notably, the desire to encourage key strategic development sectors including transportation and agriculture, are also reflected in policies designed to promote rural electrification or to keep diesel prices low.

Policies that keep key energy product prices low can also produce adverse results. Revenues from energy sales may be inadequate to cover the costs of supplying the energy. This problem is especially acute in the electricity generating sector in developing countries. One study[32] showed that in 30 out of 37 developing countries for which data were available, electricity tariffs were too low to generate the revenues needed to cover total operating costs plus allowances for equipment replacement or expansion of the system. A survey of electric power projects financed by the World Bank over a 20-year period[33] indicates a consistent decline in key financial indicators as revenues from sales of electricity lagged behind rising costs.

Petroleum prices are rather different. At present, subsidies (defined here as prices significantly lower than those charged in international markets) are largely limited to oil-exporting (or at least oil-producing) countries. Countries that import all their supplies of petroleum products, and are therefore obliged to pay current international prices for their supplies, are generally unwilling to subsidize prices on the domestic market. In the oil-exporting countries, however, despite sharp price increases in recent years, several petroleum products—notably, kerosene and heavy fuel oil-continue to be sold at half the international price or less. Low domestic gas prices, in combination with other factors, discourage the development of gas resources and contribute to the spectacularly high share of flared gas in developing countries--47 percent of total production, compared with 4 percent in the OECD countries.[34]

In both India and China, which together account for 70 percent of all coal consumption in the developing world, coal prices are kept below production costs. In China, two-thirds of all coal enterprises lost money in 1984.[35] In the early 1980s the World Bank estimated Coal India's losses at $300 million on sales of $700 million.[36]

31For further discussion of the scope and objectives of energy pricing, see Mohan Munasinghe, *Energy Analysis and Policy* (London: Butterworths, 1990); Lawrence J. Hill, *Energy Price Reform in Developing Countries: Issues and Options (Oak* Ridge, TN: Oak Ridge National Laboratory, August 1987), and Corazon Siddayao, Criteria *for Energy Pricing Policy* (London: Graham and Trotman, 1985).

32Lawrence J. Hill, op. cit., footnote 31, pp. 2-10 and 2-20, table 2-3.

33World Bank, "Review of World Bank Lending for Electric Power, " Industry and Energy Department Working Paper, Energy Series paper No. 2, March 1988.

34Mark Kosmo, Money *to Burn? The High Cost of Energy Subsidies* (Washington, DC: *world Resources* Institute, 1987), p. 14. Based on International Energy Agency data.

35Lawrence J. Hill, op. cit., footnote 31.

36Mark Kosmo, op. cit., footnote 34, p. 16.

In some cases, the costs of energy supplies are also higher than necessary. Factors such as excessive staffing and poor management in the electricity sector increase costs, and there are similar inefficiencies in the oil supply sector. Insofar as the population is aware of these problems, they maybe reluctant to agree to price increases that would in effect subsidize the inefficiencies of the supply system. Improved efficiencies on the supply side might make increases in prices and tariffs more palatable and also help to minimize the total cost to consumers.

In addition to the general level of energy prices, the structure of energy prices is of concern in both the electricity and petroleum product markets. Major differences in the prices charged for similar services--as in the case of electricity--or for petroleum products that can be substituted for each other—have given rise to distortions in product demand. The subsidization of some fuels (kerosene and diesel fuels) for general economic and social reasons, combined with high taxes on others (gasoline), leads to shortages of the subsidized fuels, surpluses of the highly taxed fuels, and capital investment decisions made on the basis of energy costs that do not reflect the cost of providing that energy.

In Thailand in the early 1980s, for example, price differences between gasoline, diesel, kerosene, and liquid petroleum gas (LPG) led to shortages and black markets in kerosene and LPG; the diversion of half of the total kerosene supply to the transport sector to adulterate diesel fuel; dieselization of many older vehicles by retrofitting a spark ignition engine to use diesel fuel; widespread theft of diesel fuel; and surpluses of gasoline as all vehicles used commercially changed over to diesel.[37] Similar developments in other countries have contributed to serious refinery imbalances. In recent years, Thailand has moved to reform its petroleum product pricing system, but wide price differentials persist in other countries, including Indonesia and India.

Energy pricing decisions are often motivated by the need to keep energy affordable for large populations of poor households. However, the practical implementation of such policy is difficult. It is often difficult to "target" disadvantaged groups. Energy consumption surveys indicate that the use of commercial fuels is concentrated among middle and upper income households, rather than the poor who rely mainly on wood and charcoal. Moreover, if subsidy programs expand in scale, they can lead to outcomes that penalize the very people they are designed to help. Thus, the deteriorating revenue situation of electricity systems, attributable in some measure to subsidized tariffs, leads to declining quality and availability of power supplies, which can cause factories and workshops to stop operations, thus increasing unemployment.

Though important, pricing is just one mechanism for influencing energy demand. Others include measures to inform consumers of cost-effective opportunities to save energy, the imposition of technical efficiency standards, and sponsorship of energy-efficient technologies.

Developing countries, frequently aided by donor countries and organizations, have made some progress in demand management and conservation. For example, the Association of South-East Asian Nations (ASEAN) countries (see box 2-B) have been particularly active in conservation in both industries and buildings. In addition, China has established energy conservation technical centers, which have contributed to the sharp decline in China's energy intensity. In Brazil, energy-saving protocols have been established with major industries. Korea has conducted major audits of large companies. Traffic management schemes, designed mainly to alleviate congestion, but with an energy-saving bonus, have been introduced in Brazil, Singapore, Thailand, and Venezuela. New, more energy-efficient automobile technologies have been introduced in India. And several improved wood-burning stoves have been introduced, at least one of which appears to have enjoyed considerable success.[38] On the institutional side, movements toward deregulation of economic activity, as in China in the 1980s, have improved the competitive environment under which energy decisions are taken and thus have contributed to improved energy efficiency.

[37] Donald Hertzmark, "Energy Efficiency and Energy Pricing in Developing Countries," op. cit., footnote 26.

[38] Samuel Baldwin, Howard Geller, Gautan Dutt, and N.H. Ravindramath, "Improved Woodburnin g Cookstoves: Signs of Success,' *AMBIO*, vol. 14, No. 4-5, 1985, pp. 280-287.

Box 2-B—Energy Conservation Initiatives in ASEAN Countries

In Southeast Asia, many governments are adopting and implementing laws to encourage energy conservation in buildings and industry. Design standards have been enact@ or are being considered, in most ASEAN countries.

In Malaysia, the Ministry of Energy, Telecommunications, and Posts has embarked on development of energy standards for new buildings, with the goal of reducing overall usage by 10 percent by 1991 (5 to 15 percent for lighting, 5 to 10 percent for air-conditioning, and 15 to 20 percent relating to heat gain through building envelopes). These standards were widely circulated for review, and were expected to be implemented during 1989. Some energy audits have been commissioned.[1]

In the Philippines, major energy consumers are required by law to have energy management programs, and large customers must report their consumption to the Office of Energy Affairs (OEA) quarterly. The OEA offers a wide range of conservation services, including an energy management training program, energy conservation briefings, industry-specific publications, assistance to the Energy Management Association of the Philippines (a private-sector group), consulting and audits, efficiency testing, and industrial efficiency monitoring. The Omnibus Energy Conservation Law mandates the development of standards for energy use in commercial buildings, for building construction materials, and for designs of commercial and industrial buildings prior to the issuance of permits for building or for adding equipment such as air-conditioning units.

Singapore encourages conservation through educational programs. Indirect controls imposed by the government's Building Control Department standardize various design features, such as overhangs and reduced window area to decrease demands for air conditioning.

In Thailand, the government's Sixth National Economic and Social Development Plan (1987-91) specified targets for increased efficiency in transportation, industry, and households. Tax reductions and low-interest loans for energy conservation equipment are available.

[1]The 1986 standards instituted in Malaysia areas follows: 1) Buildings whose connected electric service is over 250 kVA are required to have separate meters for lighting and outlets and for air conditioning systems. 2) Lighting loads are specified for interior spaces, several building interiors, and roads and grounds in the vicinity of the building. Lighting controls are specified. 3) For air conditioning, dry bulb temperatures are set at 25 degrees Celsius and relative humidity at 65 percent, plus or minus 5 percent. Automatic setback and shutoff systems are required.

Energy and The Traditional Sector

Two-thirds of the developing world's population—some 2.5 billion people--live in rural areas[39] with low standards of living based largely on low-resource farming. This type of farming is characterized by high labor requirements, low productivity per hectare and, because of the marginal subsistence, strong risk aversion. Rural populations have little access to commercial fuels and technologies and only limited connection with the modern economy. Biomass fuels satisfy the heating and cooking needs of these populations, and muscle power largely provides for their agricultural, industrial, and transportation energy needs. Although these energy sources provide crucial energy services at little or no direct financial cost, biomass fuels, muscle power, and related traditional technologies generally have low efficiencies and limited output and productivity levels (see ch. 3).

In many areas, biomass supplies are diminishing due to a host of factors, including population growth and the expansion of agricultural lands, commercial logging, and fuelwood use (see ch. 5). The poorest rural people often have limited access to even these resources and, therefore, must spend longer periods of time foraging for fuel sources--exacerbating their already difficult economic position.

Traditional villages are complex, highly interconnected systems that are carefully tuned to their environment and the harsh realities of surviving on meager resources.[40] Because the villages are largely closed systems, changes in any one part affect other

[39]World Bank, *World Development Report 1989,* op. cit., footnote 1.

@See, for example, M.B. Coughenour et al., "Energy Extraction and Use in a Nomadic Pastoral Ecosystem," *Science,* vol. 230, No. 4726, Nov. 8, 1985, pp. 619-625; J.S. Singh, Uma Pandey, and A.K. Tiwari, "Man and Forests: A Central Himalayan Case Study," *AMBIO,* vol. 13, No. 2, 1984, pp. 80-87; Amulya Kumar and N. Reddy, "An Indian Village Agricultural Ecosystem-Case Study of Ungra Village, Part II: Discussion" *Biomass,* vol. 1, 1981, pp. 77-88.

elements of village life. Changes in agricultural practices, for example, change the amount and type of energy supplies available. In turn, energy sector developments, such as rural electrification, can have major impacts on agricultural practice and income distribution. Making changes in rural systems frequently proves difficult due to the large risks that changes can pose to populations living on the margin of subsistence.

The following sections examine four of the major factors that affect the linkages between energy and the economic and social development of rural economies: seasonality; inequities in the distribution of and access to resources; the role of commercial biomass in the rural economy; and gender issues in labor. Mechanizing the mundane tasks of rural life, a process facilitated by the introduction of modern fuels, could greatly increase the productivity of rural peoples. To bring about improvements, however, will require paying close attention to the numerous related complications, such as seasonality, the type of task, culture-specific labor roles, children's labor, and many others.

Seasonality

The seasons affect every aspect of rural life: the availability of food, fuel, and employment; the incidence of disease; and even the rates of fertility and mortality.[41] Labor requirements for planting are seasonally peaked to take advantage of limited rainfall and other favorable growing conditions. When rains begin, soil bacteria multiply rapidly and break down the dead plant matter in the soil left by the dry season; this process releases a large amount of organic nitrogen in the soil. Crops planted quickly after the rainfall can take advantage of this nitrogen, but a short delay leaves weeds as the main beneficiaries.[42] Labor requirements to harvest crops are similarly peaked (see figure 2-9). Thus, while there may be a large labor surplus during most of the year, labor shortages occur during the critical planting and harvesting seasons. Studies of African agriculture indicate that labor is "the major scarce resource in food production."[43]

Modern equipment could reduce the high labor demands during planting and harvesting. Even when the necessary commercial fuels are available, however, modern agricultural equipment is often prohibitively costly to purchase or rent due to the very short period in which it can be profitably used.[44] Relatively low-cost traditional technologies face similar cost barriers. For example, the average animal-drawn cart in Ungra, India, is used at just 6 percent of its annual capacity.[45]

Draft animal technologies can ease critical seasonal labor shortages to some extent. Draft animals, however, can only be used productively for little more than the short growing season, yet these animals require food year round. Limited uses for draft animals, coupled with their high food requirements, reduce the average draft animal efficiencies to just a few percent. Because of the limited supplies of fodder available, farmers often semi-starve draft animals in order to save fodder for when the animals need their strength to plow the dry-baked ground or for other purposes.[46] A shortage of draft animals may limit crops to just one per year-even in areas with potential for double cropping.[47]

Although agriculture demands very high levels of labor during the peak seasons, during the remainder of the year, rural areas experience serious under-

[41] Robert Chambers, Richard Longhurst, and Arnold Pacey (eds.), *Seasonal Dimensions to Rural Poverty* (London: Frances Pinter Publishers, Ltd., and Tottawa, NJ: Allanheld, Osmun & Co., 1981); Robert Chambers, "Rural Poverty Unperceived: Problems and Remedies," *World Development*, vol. 9, 1981, pp. 1-19.

[42] Robert Chambers, Richard Longhurst, and Arnold Pacey (eds.), *Seasonal Dimensions to Rural Poverty*, op. cit., footnote 41, pp. 10-11.

[43] Jeanne Koopman Henn, "Feeding the Cities and Feeding the Peasants: What Role for Africa's Women Farmers?" *World Development*, vol. 11, No. 12, 1983, pp. 1043-1055.

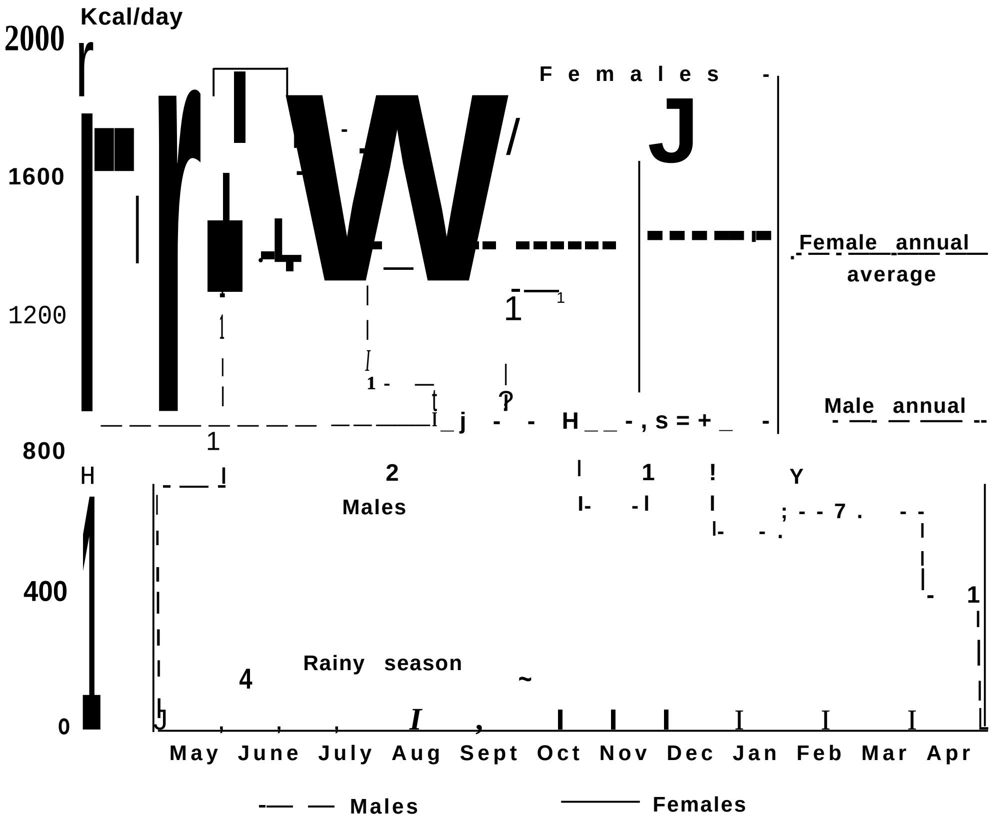
[44] Prabhu Pingali, Yves Bigot, and Hans P. Binswanger, *Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa* (Baltimore, MD: Johns Hopkins University Press for the World Bank, 1987).

[45] As a consequence of low utilization rates, villagers preferred lower cost wooden wheels over higher performance pneumatic tires until the depletion of timber resources caused the price of wooden wheels to rise significantly. At the same time, these price rises led to an active market in second-hand traditional carts. H.I. Somashekar, N.H. Ravindranath, and Amulya Kumar N. Reddy, Studies *on the Ungra Village Agricultural Ecosystem, Part III: Animal Drawn Carts and Transport* (Bangalore, India: AS-no date).

[46] H.I. Somashekar, N.H. Ravindranath, and Amulya Kumar N. Reddy, *Studies on the Ungra Village Agricultural Ecosystem Part III: Animal Drawn Carts and Transport*, op. cit., footnote 45; Jane Bartlett and David Gibbon, *Animal Draught Technology: An Annotated Bibliography* (London: ITDG, 1984); Peter Munzinger, *Animal Traction in Africa* (Eschborn, West Germany: GTZ, 1982).

[47] N.H. Ravindranath and H.N. Chanakya, "Biomass Based Energy System fOr a South Indian Village," *Biomass*, vol. 9, No. 3, 1986, pp. 215-233.

Figure 2-9-Seasonal Pattern of Energy Expenditure on Agricultural and Other Essential Tasks: Adult Farmers, Genieri Village



SOURCE: Margaret Haswell, *Energy for Subsistence* (London: MacMillan Press, Ltd., 1981).

employment. In turn, this seasonal unemployment in rural areas propels a large amount of both seasonal and permanent migration to urban areas.[48] In Africa and Asia, where the migrants are mostly men,[49] more of the burden for subsistence crop production is shifted to the women who stay behind. Migration to cities increases pressure on forests as well, because urban dwellers generally *purchase their* wood supplies, which are likely to be derived from cutting whole trees, rather than the gathering of twigs and branches as is more typical of rural foragers.

The seasons also affect the availability and usability of renewable energy resources. During the rainy season, wood is less easily obtained and more difficult to burn than during the drier months. In areas heavily dependent on crop residues for fuel, shortages at the end of the dry season can force the use of noxious weeds as substitutes, particularly by the very poor.[50] The use of biogas is limited by the availability of dung, which in Ungra, India, varies for adult cattle from 3.5 kg/day during the 7-month dry season to 7.4 kg/day during the wet season.[51] Correspondingly, in mountainous areas or elsewhere with large seasonal temperature variations, fuel demands can increase significantly during the winter. In a Kashmir village, for example, wood

[48] Michael P. Todaro, *Economic Development in the Third World (New* York, NY: Longman, Inc., 1977); Gerald M. Meier, *Leading Issues in Economic Development, 4th* ed. *(New* York, NY: Oxford University Press, 1984); Scott M. Swinton, *Peasant Farming Practices and Off-Farm Employment in Puebla, Mexico* (Ithaca, *NY:* Cornell University, 1983).

[49] Michael P. Todaro, *Economic Development in the Third World,* op. cit., footnote 48, pp. 192-193. Note that in Latin America more women than men now migrate.

[50] Varun Vidyarthi, "Energy and the Poor in an Indian Village," *World Development,* vol. 12, No. 8, 1984, pp. 821-836.

[51] N.H. Ravindranath and H.N. Chanakya, "Biomass Based Energy System for a South Indian Village," op. Cit., footnote 47.

demands during the winter are four times higher than during the summer.[52]

Inequities in Resource Distribution and Access

In regions where biomass fuel supplies are limited-particularly those with dry climates and/or high population densities-rural people may travel long distances to collect fuel for domestic use, as much as 20 miles round trip in some areas under special conditions. More generally, when wood is scarce they rely on crop wastes, animal dung, or other materials as substitutes. Estimates of time spent in foraging range as high as 200 to 300 person-days per year per household in Nepal.[53] Foraging is also heavy work. In Burkina Faso, typical headloads weigh 27 kg (60 pounds) .54 In many regions, women and children shoulder most of the burden.

Despite these heavy burdens, villagers often prefer to invest their capital and labor in technologies for income-producing activities, such as yarn spinners, rather than in fuel-conserving stoves or tree-growing efforts.[55] Reasons for this investment preference include lack of cash income; the ability to minimize wood use or to switch to alternative fuels when wood becomes scarce;[56] conflicts over ownership of land or trees; and easy access to common lands. In addition, villagers often carry out fuelwood collection in conjunction with other tasks, such as walking to and from the fields or herding animals. In this case, collecting biomass resources may prove less burdensome than it appears.[57]

If wood is scarce, villagers use crop wastes, dung, 'or other less desirable fuels. To the village user, the immediate value of these fuels outweighs their potential long-term environmental costs.[58] In India, for example, a ton of cow dung applied to the fields produces an estimated increase in grain production worth $8 (U.S. dollars), but if burned eliminates the need for firewood worth $27 in the market.[59] The diversion of crop residues, previously used as soil enhancers, to fuel use may lead to a long-term loss in soil fertility unless offset by increased use of chemical fertilizers.

Local fuel shortages often have their most serious impacts on rural landless and/or marginal farmers with little access to fuel supplies. The poor may also sometimes be denied access to their traditional fuel sources when the market value of biomass rises.[60] For example, farm laborers in Haryana, India, are now sometimes paid in crop residues for fuel rather than in cash, although previously they had free access to these agricultural wastes.[61]

The Role of Women

Women shoulder the burden of most domestic tasks, including foraging for fuelwood and cooking. In many areas they also perform much of the subsistence agricultural labor. A 1928 survey of 140 Sub-Saharan ethnic groups found that women "carried a major responsibility for food farming" in 85 percent of the cases, and did all but the initial land

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52Majid Hussain, "Fuel Consumption Patterns in High Altitude Zones of Kashmir and Ladakh,'' *Energy Environment Monitor* (India), vol. 3, No. 2, September 1987, pp. 57-62.

53J.S. Singh, Uma Pandey, and A.K. Tiwari, "Man and Forests: A Central Himalayan Case Study," *AMBIO*, vol. 12, No. 2,1984, pp. 80-87; Kedar Lal Shrestha, *Energy Strategies in Nepal and Technological Options* (Nepal: Research Center for Applied Science and Technology, Tribhuvan University, for the End-Use Oriented Global Energy Workshop, Sao Paulo, Brazil, June 1984). The World Bank Energy Sector Assessment for Nepal estimated that 16 percent of all labor went for fuelwood and animal fodder collection.

54E. Ernest, "Fuel Consumption Among Rural Families in Upper Volta, West Africa,'' paper presented at Eighth World Forestry Conference, Jakarta, Indonesia, 1978.

55Varun Vidyarthi, ''Energy and the Poor in an Indian Village, " op. cit., footnote 50.

56Phil O'Keefe and Barry Munslow, "Resolving the Irresolvable: The Fuelwood Problem in Eastern and Southern Africa,'' paper presented at the ESMAP Eastern and Southern Africa Household Energy Planning Seminar, Harare, Zimbabwe, Feb. 1-5, 1988.

57Irene Tinker, ''The Real Rural Energy Crisis: Women's Time," *Energy Journal*, vol. 8, 1987, pp. 125-146.

58Geoffrey Barnard and Lars Kristoferson, *Agricultural Residues as Fuel in the Third World* (Washington, DC, and London: Earthscan and International Institute for Environment and Developmen,% Energy Information Program, Technical Report No. 4, 1985).

59G.C. Aggarwal and N.T. Singh, ''Energy and Economic Returns From Cattle Dung as Manure and Fuel,'' *Energy*, vol. 9, *No.* 1, 1984, pp. 87-90; see also G.C. Aggarwal, "Judicious Use of Dung in the Third World," *Energy*, vol. 14, No. 6, 1989, pp. 349-352; Eric Eckholm et al., *Fuelwood: The Energy Crisis That Won't Go Away* (London: Earthscan, 1984), p. 105; Ken Newcombe, World Bank, Energy Department, "An Economic Justification for Rural Afforestation: The Case of Ethiopia," 1984.

60Varun Vidyarthi, ''Energy and the Poor in an Indian Village," Op. Cit., footnote 50.

61 Centre for Science and Environment, *The State of India's Environment 1984-85: The Second Citizen's Report* (New Delhi: 1985).

clearing in 40 percent of the cases.[62] In contrast, the Muslim custom of Purdah, for example, tends to keep women near their homes and away from the fields in Bangladesh.[63] As women's work often does not produce any cash revenue, opportunities for introducing energy- and labor-saving technologies for women's work are limited. Improving labor productivity and energy efficiency in rural areas will thus require special attention to the role of women.

The careless introduction of labor-saving technologies could increase the burden on women. For example, the introduction of animal or mechanical traction for land preparation and planting increases the area that men can cultivate, but does nothing to assist women in weeding, harvesting, post-harvest food preparation, storage, and other tasks.[64]

The migration of men to look for urban work leaves women to fulfill traditional male roles as well as their own. In Uttar Pradesh, India, the male:female ratio in villages is 1:1.4 for the working age group of 15 to 50 years.[65] In Kenya, a quarter of rural households are headed by women—in Botswana, 40 percent.[66] Yet the remittances of the migrants can make an important contribution to rural household finances.

Children, too, play an important role in rural labor, freeing adults to perform more difficult tasks.[67] In Bangladesh, for example, children begin performing certain tasks as early as age 4. By age 12, boys become net producers-producing more than they consume-and are nearly as efficient in wage work as men. By age 15, boys have produced more than their cumulative consumption from birth, and by 22 they have compensated for their own and one sibling's cumulative consumption.[68] The major role of children in farming helps explain high fertility rates in rural areas.

The Role of Commercial Biomass in the Rural Economy

While much biomass is used locally, rural areas are also the source of substantial amounts of fuelwood (both firewood and charcoal) used in towns.[69] This trade pumps relatively large amounts of cash into the rural economy and provides much-needed employment to rural dwellers during non-agricultural seasons. To supply Ouagadougou, Burkina Faso, with wood during 1975, for example, required some 325,000 person-days of labor and generated over $500,000 in income directly and an additional $2.5 million in income through transport and distribution.[70] Such marketing networks can be quite extensive and complex.[71]

In many countries, people in the poorest areas, where conditions do not permit expansion of crop or animal production and natural woody vegetation is the only resource, depend heavily on sales of

62Jeanne Koopman Henn, "Feeding the Cities and Feeding the Peasants: What Role for Africa's Women Farmers? " op. cit., footnote 43.

63Mead T. Cain, "The Economic Activities of children in a Village in Bangladesh," *Population and Development Review,* vol. 3, No. 3, September 1977, pp. 201-227; Gloria L. Scott and Marilyn Carr, "The Impact of Technology Choice on Rural Women in Bangladesh" World Bank, Staff Working Paper No.731, Washington DC, 1985.

64Peter Munzinger, *Animal Traction In Africa, Op.* cit., footnote 46.

65J.S. Singh, Uma Pandey, and A.K. Tiwari, "Man and Forests: A Central Himalayan Case Study," op. cit., footnote 40.

66World Bank, *Population Growth and Policies in Sub-Saharan Africa* (Washington, DC: 1986), P. 39.

67Ingrid Palmer has noted: "Children's labor, especially daughters', is usually more significant tban husbands' in easing a work bottleneck for women." Ingrid Palmer, "Seasonal Dimensions of Women's Roles," in Robert Chambers, Richard Longhurst, and Arnold Pacey (eds.), Seasonal *Dimensions to Rural Poverty,* op. cit., footnote 41.

68Mead T. Cain, "The Economic Activities of Children in a Village in Bangladesh," op. Cit., footnote *63.*

69The value of commercialized fuelwood and charcoal exceeds 10 percent of the gross domestic product in countries such as Burkina Faso, Ethiopia, and Rwanda and exceeds 5 percent in Liberia, Indonesia, Zaire, Mali, and Haiti. Philip Wade and Massimo Palmieri, "What Does Fuelwood Really Cost?" *UNASYLVA,* vol. *33, No. 131, 1981,* pp. 20-23. George F. Taylor, II, and Moustafa Soumare, "Strategies for Forestry Development in the West African Sahel: An Overview," *Rural Africana, Nos. 23* and *24,* Fall 1985 and Winter 1986.

70J.E.M. Arnold, "Wood Energy and Rural Communities," *Natural Resources Forum,* vol. *3, 1979,* pp. 229-252.

71Alain Bertrand, "Marketing Networks for Forest Fuels to Supply Urban Centers in the Sahel," *Rural Africana,* Nos. 23 and 24, Fall 1985 and Winter 1986.

firewood for their income.[72] Similarly, when crops fail, charcoal production[73]--or, as in Bangladesh, the cutting of wood from farm hedgerows grown in part as an economic buffer to be sold before more valuable livestock and land[74]—provides alternatives for earning cash. In India, for example, "headloading" (individuals carrying wood to urban markets on their heads) has become an important source of income for perhaps 2 to 3 million people .75

The response of rural peoples to fuel shortages varies widely. Some sell wood to urban markets and use the lower quality residues themselves. Others use dung for fuel rather than for fertilizer. In Malawi, to grow sufficient fuel for household use on the typical family farm would displace maize worth perhaps 30 times more; collecting "free" wood proves much easier.[76] In contrast, aerial surveys of Kenya have shown that hedgerow planting increases with population density-demonstrating that villagers respond to the reduced opportunity of collecting free wood from communal lands by growing their own.[77]

Conclusion

High rates of economic growth will be needed in developing countries to provide the rapidly growing population with improved living standards. If present trends in energy and economic growth continue into the future, a sharp increase in commercial energy consumption in developing countries will be required. Substantial increases in supplies of biomass fuels will also be needed. This prospect raises a dilemma. On the one hand, increases in energy supplies on this scale would severely strain financial, manpower, and environmental resources. But on the other, inability to supply needed energy can frustrate economic and social development.

One way to resolve this dilemma lies in distinguishing between the energy that is consumed and the services derived from it. Technological improvements and other means offer the potential of greatly improving the efficiency of energy use-providing more of the energy services needed for development while consuming less energy. The next chapter provides an introduction to the services provided by energy, and how they are currently delivered, with a view to identifying potentials for improving efficiencies.

[72] J.E.M. Arnold, "Wood Energy and Rural Communities," op. cit., footnote 70, Centre for Science and Environment, *The State of India's Environment 1984-85: The Second Citizen's Report,* op. cit., footnote 61.

[73] D.O. Hall and P.J. de Groot, "Biomass For Fuel and Food-A Parallel Necessity," draft for *Advances in Solar Energy,* Karl W. Boer (cd.), vol. 3, Jan. 10, 1986; Rafiqul Huda Chaudhury, "The Seasonality of Prices and Wages in Bangladesh," in Robert Chambers, Richard Longhurst, and Arnold Pacey (eds.), *Seasonal Dimensions to Rural Poverty,* op. cit., footnote 41.

[74] Rick J. Van Den Beldt, "Supplying Firewood for Household Energy," in M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds.), *Rural Energy To Meet Development Needs* (Boulder, CO: WestView Press, 1984).

[75] Centre for Science and Environment, *The State of India's Environment* 1984-85: *The Second Citizen' sReport,* op. cit., footnote 61, p. 189.

[76] D. French, "The Economics of BioEnergy in Developing Countries," in H. Egneus et al. (eds.), *Bioenergy 84, Volume V: Bioenergy in Developing Countries* (Amsterdam: Elsevier, 1985). It is estimated that 90 percent ofall rural households collect all their woo@10 percent purchase some of their wood at $0.50/m^3$ or $0.04/GJ. Urban households buy their wood at a cost of $0.12/GJ. In contrast, plantation-derived fuelwood can cost $1.50 to $2.00/GJ. A farmer could plant trees, but the loss of 0.4 hectare of farmland reduces maize production by a total of $125 and profit by $30. contrast, trees produced on 0.4 hectare will be worth $6 in 7 years.

[77] P.N. Bradley, N. Chavangi, and A. Van Gelder, "Development Research and Energy Planning in Kenya," *AMBIO,* vol. 14, Nos. 4-5, 1985, PP. 228-236.