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Energy and the Oil-Importing Developing Countries

Joy Dunkerley and William Ramsay

The oil-importing developing countries are a critical segment of the global energy, economic, and environmental scene (*1, 2*). Their oil imports currently represent some 5.5 million barrels per day (MBD) or 20 percent of the total oil exports of the Organization of Petroleum Exporting Countries (OPEC), but within 10 years their share is estimated to attain more than one-quarter of the total (*3, 4*). Indeed, from now to 1990, the oil-importing developing countries could account for all of the increase in demand for OPEC oil exports (*5*). What happens in these countries will therefore have a major impact on the course of oil prices, in which all importing countries, whether rich or poor, have a vital interest.

The ways in which the oil-importing developing nations finance these rising oil imports also has an impact on the rest of the world. High levels of debt, made necessary to finance increasing import bills, threaten the stability of the international financial system. Alternatively, if the oil-importing developing countries are unable to afford more oil, their growth rate will suffer, threatening major export markets for the industrial countries and, ultimately, regional and global peace.

The linkage between the developing and the industrial world also extends to the developing countries' use of traditional fuels. Overuse of traditional fuels such as wood and crop and animal wastes can result in lowered agricultural productivity; loss of virgin tropical forest leads to extinction of plant and animal species; carbon dioxide emissions from clearing of large areas of tropical forests could contribute to a global climate change.

Generalizations about the energy problems of developing countries and the solutions to them are difficult. These countries form a spectrum ranging from stagnating, abysmally poor countries to rapidly growing middle-income countries, like Korea and Brazil, with annual per capita incomes of $1500 or more. The latter countries have such large and dynamic manufacturing sectors that they are close to being industrialized nations. At the other end of the spectrum are countries like Burundi and Upper Volta with per capita incomes of under $200 a year. This wide variation in standards of living is reflected in the amounts of energy consumed. Per capita consumption of commercial energy in Korea, for example, is 60 to 80 times higher than it is in the above-mentioned African countries. So, although these countries share a common set of energy problems stemming mainly from their dependence on imported oil, they are affected by higher oil prices to different degrees, have different possibilities for solving their problems, and require different types of help.

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The Crux of the Energy Problem

The basic energy problem for these countries as a group is how to secure adequate and reliable quantities of energy to meet minimal economic needs and maintain development rates. Increased supplies of traditional as well as commercial fuels (oil, gas, coal, and electricity) will be needed. It is no longer possible to assume, as in the past, that traditional fuels will be phased out of the energy sector of these countries (*6*). If per capita consumption of traditional fuels in rural areas remains fairly constant, availabilities will have to increase by about 2 percent annually. But this rate will need to rise if consumers—households and even some industries—start, in response to higher oil prices, substituting traditional for commercial fuels on a significant scale or if biomass feedstocks are needed for new commercial fuels such as methanol. For commercial fuels themselves, the increase in consumption should be even greater. Recent estimates (*7*) suggest that, given expected population and economic growth rates, consumption of commercial fuels in the oil-importing developing countries could rise by about 6 percent annually up to 1990. Although this is a lower rate of increase than that experienced before 1973, it is still comparatively high in one important sense: it implies a more than doubling in real terms of already high oil import bills.

Commercial fuels. Increasing supplies of traditional and commercial fuels will raise problems. The developing countries are already heavily dependent (67 percent) on oil, the fuel that has risen most sharply in price. Although several of the oil-importing countries produce some oil, by far the largest share of their supplies comes from abroad. Indeed, imported oil is the mainstay of their commercial energy supplies. The sharp increases in oil prices that took place in 1973 to 1974 and in 1979 to 1980, therefore, created major problems of economic management for these countries. Insofar as oil prices are expected to rise in the future, such problems are likely to recur.

Higher oil prices contributed, for example, to the tenfold increase in trade deficits and the sixfold increase in debt over the last 9 years. Servicing costs have risen even more rapidly than debt—from $8 billion in 1971 to $75 billion in 1980—reflecting higher interest rates and shorter maturities (*8*). On the average, 10 percent of the total export earnings of these countries had to be earmarked to pay for existing debt in 1979, and that proportion will have risen since then (*3*, p. 158). Within the group of developing countries, the debt service ratios of the poorest countries are very much higher than the average, even though they have not had access to the private long-term capital flows, which accounted for 80 percent of the debt increase of all developing countries. Even among the middle-income group, however, there are countries—Brazil, Bolivia, and Chile, for example—whose debt service ratios are well over 20 percent.

In the domestic economy, higher prices of imported fuels contributed to accelerated inflation and to lower economic growth. It is true that the economies of the oil-importing developing countries as a group, which had grown by an annual average of 6 percent up to 1972, fell by only 1 percentage point after 1973, to 5 percent (*9*); this economic performance was better than that achieved by the industrial countries. But the point is that even a modest reduction in economic growth is a serious matter for countries that depend on rapid growth to reduce widespread poverty. To make things worse, the record of economic growth within this group of countries was uneven. The lowest rates of growth were experienced by the poorest countries. Many African countries—for example, Ethiopia, Zaire, Uganda, Ghana, Mozambique, and Zambia—experienced a substantial decline in living standards in the 1970's. Projections of economic activity for this group of countries indicate that probably the most that can be hoped for is to arrest this decline so that the citizens of these countries at least do not become even poorer (*3*, p. 3).

Traditional fuels. The position for traditional fuels, particularly for forest products, which provide about 70 percent of total traditional fuel supplies, is also not strong. The resource base of the tropical forests is presently under considerable stress, losing more than 10 million hectares annually (*10*). In certain regions and countries, losses have been much more severe.

The results of a shrinking forest resource base are important and far-reaching. A special hardship is imposed on the rural poor, as firewood is the major, perhaps the only, form of fuel available to 2 billion people, about one-half of the world's population (*11*). While the data are poor, it has been estimated that buying wood fuels in some cities of the Sahel requires one-fourth to one-third of the average laborer's income. In other areas, Nepal and central Tanzania, it has been claimed that it takes 200 to 300 person days of work per year to gather a family's fuelwood (*12*), and in Bujumbura, Burundi, a low-income household reportedly spends $40 a month on charcoal, almost half its average budget (*2*).

Furthermore, while traditional sources of traditional fuels are becoming hard pressed, one of the few practical medium-term means of escape from excessive oil dependence is to use biomass resources in new ways. Thus, ironically, the biomass resource in developing countries is in great danger just at the time when wood and other biomass fuels are needed to replace oil in generating plants and gasoline in vehicles.

The destruction of forest and ground cover also has serious environmental consequences for topsoil and watersheds. Shortages of wood for fuel lead to increased use of crop and animal residues, which otherwise would have added nutrients to the soil.

The severity of these problems differs from country to country. Some countries—Colombia, Chile, Brazil, and several Caribbean countries—are so well endowed with forest resources that they are considered unlikely to experience national shortages, although local shortages can still develop even in well-wooded regions. Many more countries are likely to develop problems of widespread severity. These include India, Pakistan, Bangladesh, and many of the poorer African countries.

Summary. Oil-importing developing countries will need more energy during the 1980's to sustain development and to support their subsistence sectors. Development plans must be revised to reflect the potentially disastrous effects of high-cost oil on foreign exchange reserves and on national indebtedness. Energy use efficiency must be increased, and wider use must be made of domestic sources of energy—of conventional fossil and hydro sources and of new and renewable options such as biomass and other solar resources. The international community can help by careful management of world financial flows and trade agreements, expansion of capital assistance, and provision of technical assistance. The importance of improving levels of scientific and technical expertise in the less-developed countries is a challege to the worldwide scientific and engineering community.

Energy and Economic Policy

Although more energy will be needed in the future, one must remember that energy is valued not for itself, but for the contribution it makes to economic growth and the satisfaction of minimal needs for cooking and heating. The goal of all of these countries is to promote development, not to minimize energy imports at all costs. A "Project Independence" approach can appear as attractive to oil-importing developing countries as it does to others, but other approaches can be better and cheaper. It may, for example, prove cheaper and almost as effective to guard against some types of oil insecurity by building up stockpiles against possible supply disruption, or diversifying the source of imported oil so that if one supplying country does not deliver, other well-established sources remain.

For some developing countries, especially those with major manufacturing export sectors, export promotion to earn the foreign exchange for higher priced oil may be a highly effective policy. This certainly seems to have been the most successful approach for several countries in the years after 1973. Recent studies (*13*) trace the effects of higher oil prices and other shocks—such as a slowdown in world demand for exports—and subsequent economic policies on the balance of payments and growth rates of 24 countries, including 12 newly industrializing countries (NIC's) (*14*) and 12 other less-developed countries, not including the poorest nations of Africa and Asia.

Among these countries a distinction is drawn between "outward-looking" economies (such as Singapore and Korea), whose development strategies are geared to export-oriented industrialization, and "inward-looking" economies (such as Brazil and India), whose strategy promotes import-substituting industrialization. The results of these studies indicate that within both the NIC's and the other group, the "outward-oriented" economies, although suffering greater external shocks in 1973 to 1974, made the more successful domestic adjustment. Among the NIC's, for example, growth rates in the outward-oriented countries decreased from 7.4 percent before 1973 to 5.9 percent during 1973 to 1976, but rose again to 9.7 percent during 1976 to 1979. In NIC's that followed inward-oriented policies, rates of growth fell from 6.9 percent before 1973 to 5.0 percent in 1976 and did not recover in subsequent years. Debt service ratios are also much higher in the inward-oriented economies than in the others.

There are several lessons to be drawn. The first is the importance of adopting correct policies to offset the effects of the oil shock. Among the countries examined, the outward-looking economies were more successful in setting realistic exchange rates and providing adequate incentives for savings and investment. Second, the outward-looking policy is a feasible option for many countries, not only NIC's. It does not, however, seem a realistic option for the poorer countries of Africa and Asia, where overall development problems predominate and lack of resilience or economic infrastructure hampers adjustment to oil price shocks. For these countries, renewed efforts to achieve traditional goals are needed, such as revolutionizing yields in the agricultural sector through new technology and better infrastructure and management. Finally, the most effective single way of helping the oil importers of developing countries to cope with higher import bills may be for the industrial countries to make the outward-oriented strategy work by keeping down market barriers to exports from the developing countries.

Energy and Development Strategies

Concern for the efficient use of resources after increases in oil prices also has implications for the relation between energy and development. While a concentration on the energy sector to the detriment of other aspects of economic activity must be avoided, the energy implications of development strategies must be understood as never before. This is often more complicated than it sounds, as the necessary processes of consultation cut across traditional ways of conducting business in most governments. Ministries or Departments of Energy—if they exist—are usually charged with planning and overseeing the energy sector. But equally important decisions affecting energy use and availabilities are frequently made outside the Energy Department, in, for example, the Departments of Transportation, Agriculture, or Industry. It is therefore important to ensure that the effects on energy of decisions made in other sectors are integrated into the planning process.

Energy considerations are of particular relevance in making choices among development tactics—for example, on the types of industrial development to encourage. Planning for industrial development must, of course, take into account all factors of production, but there is a range of important industries—iron and steel, chemicals, plastics—in which high-cost energy is a major constraint. When oil was cheap and supplies were readily available, it was possible for countries without major domestic energy reserves to develop such industries. But there is already evidence that some countries are taking steps to discourage such energy-intensive industries. In Korea, for example, new investments in energy-intensive industries such as aluminum, steel, and fertilizers are to be allowed only under exceptional circumstances, and they will not be eligible for the customary subsidies and preferential tax and interest rates (*15*).

Increasing Domestic Energy Production

Even though the necessarily changed role of energy in development is recognized, more energy and more efficient use of energy is still needed. Increasing energy production at home has become a major goal for most developing countries. Unfortunately, for some unfavored countries, domestic energy resources of any kind seem scarce; in others, energy is waiting to be found, or known energy resources are not being developed, because technology or information is lacking.

Energy resource problems and possibilities can be of many kinds. We review here only a few key options among many. There are grounds for both pessimism and optimism, for example, in finding new oil and gas reserves in developing countries. On the optimistic side, it is suspected that many countries have not been adequately investigated for oil and gas. Although 50 percent of all exploratory wells outside North America in the decade from 1967 to 1976 were reported as having been drilled in non-OPEC developing nations (*16*), the vast majority of these wells (5416 of 6501) were sunk in 16 countries where significant discoveries had already been made before 1967. But on the gloomy side, it has been estimated that only about 10 to 25 percent of the total amount of ultimately recoverable petroleum in the world will be found from entirely new discoveries—such as in most of the present oil-importing developing nations (*17*). Nevertheless, no one denies that new small- and medium-sized fields could be found that would be adequate to provide part, if not all, of the commercial energy requirements of many of these countries. For instance, while the cost of oil imports has risen more than five times since 1975 (*2*) in the small land-locked country of Burundi, it used only 47,000

metric tons of oil in 1980—which could be supplied by a hypothetical oil find of a very small size. Encouragement has been found in oil discoveries in five countries (Benin, Chad, Niger, Ivory Coast, and Sudan) that are not producers at present, and others (for example, Brazil, Chile, and Pakistan) are actively trying to increase exploration efforts.

The recent rises in oil prices have also renewed interest in coal—at one time the mainstay of the world's energy economy. Developing countries are estimated to have about 10 percent of world economically recoverable reserves, while having only 2 percent of total estimated or "geological" resources (*1*, p. 142). This discrepancy is almost certainly due to lack of past interest in exploration for coal. Significant deposits exist in many African countries (Nigeria, Zimbabwe, Swaziland, and Botswana); new estimates of resources tend to be much higher than older estimates in Colombia and Brazil; and new sources of coal in Asia may include Bangladesh, Taiwan, Korea, the Philippines, and Indonesia. Even if countries do not have domestic coal, imported coal in a competitive market could be a viable alternative to imported oil. The coal import option is also a potentially intriguing possibility for cooperation between developing nations and the coal producers of the Organization for Economic Cooperation and Development.

Another underutilized resource is uranium. Although known uranium resources in the oil-importing Third World are relatively small, exploration has been limited, and there is reason to believe that undiscovered resources are relatively widely distributed (*18*). Nevertheless, in view of current technical and political problems in the nuclear area, domestic use of nuclear energy might be fraught with difficulties (*1*, pp. 190–192), and exports of domestic uranium ore might face an uncertain market.

The oil-importing developing countries are often relatively highly endowed with renewable energy resources. The amount of hydroelectricity available in some developing countries is very large compared with foreseeable future needs. Thus, in Africa, only about 2 percent of the hydro potential is now developed; for Asia the total is 8 percent, and for Latin America 6 percent (*1*, p. 157). These may be underestimates, not fully taking into account recent higher costs of thermal generation, or the potential for small-scale projects. For example, there are only 621 megawatts of capacity in hydroelectric plants now extant or under construction in Costa Rica, with 1775 megawatts projected in the year 2000 (*19*). But the total potential resource has been estimated at some 9000 megawatts (*20*).

Table 1. Theoretical annual energy resources from existing forest and waste biomass in developing countries (*35*).

Region	Total theoretical annual energy from biomass (million metric tons of oil equivalent)	Commercial energy consumption in 1976 (million metric tons of oil equivalent)	Ratio of 1976 consumption to theoretical total
Latin America	370 to 2000	218	1.7 to 9.2
Africa	280 to 1900	43	6.5 to 44
Asia	650 to 1700	251	2.6 to 6.8

The hydroelectric resource is of special interest as far as engineering policy is concerned. In many nations, hydroelectric facilities may constitute one of the most important repositories of national engineering talent. One might speculate from this fact that additions to hydropower—both conventional and mini-hydro schemes—could turn out to be "culturally" easier to implement than some other energy options.

Solar resources, both direct and indirect, are bound to play larger roles in the Third World. Photovoltaic systems are useful for generating small but critical amounts of power in remote locations, especially to power refrigerators and other equipment in rural health centers. Photovoltaic systems worth $3.5 million are to be installed in 30 developing countries over the next few years by U.S. firms, and the government of India has recently approved a proposal to build two 10-megawatt-capacity photovoltaic plants of its own (*21*).

Geothermal resources also tend to be relatively high in quality in much of the developing world. Central American geothermal electric potential may be over 9000 megawatts, and in El Salvador even present electricity production, other than hydroelectricity, is one-third geothermal (*22*).

Significant biomass resources exist in most nonarid countries, are potentially very abundant for many countries, and are perhaps the only significant energy resource for practical near-term use in some. For all three developing continents, theoretical annual supplies of energy from forest growth and from manure and crop residues exceed current levels of commercial energy consumption by a considerable margin (*1*, p. 178) (Table 1). Even at the lower limits, theoretical supplies of biomass in Latin America and Asia are about double the current levels of consumption of commercial fuels. In Africa the margin is much greater (*23*).

The emphasis here must be on "theoretical." As we have seen, forest lands are already under pressure. Although data are poor, there are indications that forest resource depletion is highly correlated with energy consumption, as well as with population growth (*24*). To turn this situation around, the forests of the developing world would have to be more efficiently managed to produce a sustained yield of wood for energy and other uses. This means that determined efforts would have to be made to produce forest products both in plantation and village woodlots on a continuous basis, and to improve yields through better harvesting practices, fertilization, and genetic research. Indeed, recent advances in genetic engineering for crop improvement in the United States have great potential—short-term, for tissue culture—and longer term, with molecular genetics (*25*) for revolutionizing energy (and food and fiber) biomass in developing areas.

Such programs could, besides contributing to energy supplies, particularly benefit the rural poor and produce important environmental and agricultural benefits. Regardless of the need for additional world supplies for energy—in the form of fuelwood and new forms such as fuel alcohols—the developing countries must pay more attention to the forests in order to protect their watersheds. Indeed, one of the strongest recommendations coming from the 1981 U.N. Conference on New and Renewable Sources of Energy was for adequate management of forest resources (*26*).

The development of these potential resources depends on a variety of factors. The fivefold increase in real prices of petroleum has improved the competitive standing of many forms of energy that compete with imported oil (*27*). But the rise in oil prices, although a necessary condition of increased domestic production, may not in itself be sufficient to elicit major increases in production. Government price control policies, may,

for example, blunt the incentive offered to potential producers. And, even if correct pricing policies were in place, institutional constraints could still deter development. Potential producers, such as international companies, might hesitate to undertake energy projects despite high prices because of fear of expropriation and uncertainty about their future freedom of action, or because of structural factors like the little-understood problems of vertical integration within the industry (*28*). From the host country's point of view, agreements with foreign companies involve delicate issues such as desired depletion rates and other problems thought of as impinging on national sovereignty and local control of natural resources.

Furthermore, the development of potential energy resources will require a major mobilization of resources; the World Bank estimates the investment needs of the energy sector in developing countries at over $50 billion a year (1980 dollars) over the next 10 years, double the present level (*29*). Infrastructure will be needed and energy technologies must be transferred and adapted to local conditions. Additional demands will be made on domestic savings, management, and skilled labor, which may already be in short supply.

One popular answer to some of these problems has been widespread encouragement of "appropriate" schemes, especially village technology, on the assumption that such schemes mobilize indigenous potential labor and capital resources more effectively than conventional energy development approaches do. Although long-term financial costs of small wind generators, household biogas units, and other village options are difficult to estimate, indirect effects on village life could be of great importance; equitable income distribution and local employment, for example, could conceivably be improved (*1*, pp. 203–211). At the same time, substantial changes in village economies have traditionally been difficult to make, and problems must often be overcome in, for example, providing infrastructural elements such as transport, credit, and repair facilities that may be needed to make village-scale projects successful (*30*).

Improving Energy Efficiency

Attention to improving the efficiency with which energy, and particularly petroleum, is used can also help to ease the adjustment to higher oil prices. There is evidence in all sectors that opportunities exist to save energy even at low consumption levels (*31, 32*). In the transport sector, which typically uses 40 percent of total oil supplies in developing countries, variations in passenger car ownership and in gasoline consumption among the developing countries suggest that savings in gasoline could be achieved without adverse effects on economic growth or welfare. In Brazil, for example, there are 40 passenger cars per million dollars of gross domestic product compared with only four in Korea (*1*, p. 113). In industry, wide variations in the amounts of energy used in similar industrial processes suggest that energy could be saved—either through "housekeeping" changes or through more substantial changes in processes. A recent study in Ecuador showed, for example, that in the soft drink industry, energy intensity varied by an order of magnitude for similar processes (*32*, p. 35). More generally, reports on industrial energy use for several countries suggest that savings on the order of 20 percent in industrial energy could be achieved without major investments in process changes.

In the industrial, thermal electric, and residential sectors there are possibilities for substituting other fuels for oil—gas, if available, but also coal or wood. Important opportunities for saving traditional fuels exist through the introduction of more efficient cooking stoves; however, the existence of opportunities should not disguise the potential social as well as economic difficulties of saving energy through introducing fundamental changes in household behavior (*33*).

As with domestic supplies, higher oil prices will encourage conservation of energy in general and of oil in particular. But again, conserving oil may clash with other objectives; in many countries, prices of selected energy products such as kerosene have traditionally been subsidized, both to protect the forests and to ensure that the poor have access to energy. In the present combined crisis of oil supplies and biomass resources, new policies that may be difficult to enforce must be developed to replace the potentially disastrous subsidization of oil products.

Even if the structure and level of prices fully reflect long-run costs of acquiring energy, constraints in achieving conservation could persist. Domestic and industrial users may lack the expertise or resources to make the necessary investments. Supplementary policies, such as low-interest loans for energy conservation and training schemes for the energy conservation staff, may then be needed.

The Role of International Assistance

The main burden of structural adjustment and resource mobilization will fall on the public authorities and the private sectors of the oil-importing developing countries. But the process could be eased by assistance from the industrial countries, motivated not only by humanitarian concerns, but also by the awareness of the linkages between developments in the oil-importing developing countries and their own well-being. This assistance could take the following forms:

1) Facilitating the efficient recycling of surplus OPEC funds and coming up with new answers for the problem of debt in the developing country.

2) Keeping import markets free of barriers in order to permit the developing countries to pay higher import bills by increasing their exports.

3) Helping to finance costs of domestic energy programs, both of supply and conservation. Although the costs are large, the burden of meeting them could be eased by multilateral and bilateral aid and the encouragement of private investment. With high petroleum prices, such investments could bring high rates of return to domestic and foreign investors alike.

4) Giving technical assistance, especially to the poorer countries, in energy planning and resource exploration and appraisal, and coupling this with integrated and well-planned projects for the transfer of energy technology already developed in the industrial nations. Technology transfer can include everything from forestry management techniques, through alcohol fuel technology, to instructions in energy conservation. But to be effective, it must be consistent with national objectives and with sensible overall energy and development goals. The importance of improving levels of scientific and technical expertise in such programs is both a problem and a challenge to the worldwide scientific and engineering fraternity.

5) Developing regional agreements, such as that between Venezuela, Mexico, and a group of Central American and Caribbean countries, that link oil purchases to the granting of loans on favorable terms for energy development.

6) Facilitating new energy markets, such as an enhanced worldwide coal trade and the institution of regional electric grids to enable sharing of hydroelectricity.

The relevance of these different types of assistance would vary from country to country. For many of the middle-income

countries where adequate infrastructure already exists, it may be sufficient to provide access to markets and new technology and help with debt if necessary. But the problems of the poorer oil-importing developing countries may be more intractable; these countries will require different forms of assistance, relying much more heavily on direct technical assistance and concessional aid.

Conclusion

The energy situation in oil-importing developing nations threatens their future development and thereby the world political order itself. A number of options for adjusting to higher oil prices are available; in practice each country would use a mix appropriate to its own resource base and level of development. The possibility of increasing export earnings could be realized by policy changes in many countries, including particularly those that already have a significant export trade in manufactures (and may be the only answer for some countries poorly endowed with energy). Those countries with fossil fuel resources should press ahead with their development. Similarly, many countries have important hydroelectric resources to develop. Almost all countries should pay more attention to biomass—not only to correct existing difficulties, but also to ensure that biomass, which for very many countries is their most plentiful resource, plays a larger and more efficient role in their energy economies.

Attention should also be paid to conservation—not in reducing energy consumption, but rather in reducing the rate of growth in energy consumption that will be necessary if development is to take place. This may include both increasing the efficiency with which energy is used and the reorientation of development strategy in view of higher energy prices.

The balance between increased production and conservation would have to be determined in each case. As a general order of magnitude, the World Bank estimated that oil import savings by 1990 from an aggressive conservation and fuel switching policy could be as great (about 1.2 MBD) as a maximum effort to raise oil production. Together these actions could reduce oil bills by as much as $30 billion in 1990 (*34*).

The international community can help in this process by giving technical assistance at the right places, by better management of world financial flows and trade agreements, and by careful expansion of capital assistance to the oil-importing developing countries to seize cost-effective opportunities for energy conservation and increases in domestic energy supplies.

References and Notes

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4. See for example (*3*, p. 36). One MBD equals about 50 million metric tons of oil equivalent. One metric ton of oil equivalent is taken here to be equal to 43.1×10^9 joules.
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35. Adapted from (*1*), p. 170; one metric ton of oil equivalent here equals 43.1×10^9 joules.

36. This article is based on material contained in J. Dunkerley, W. Ramsay, L. Gordon, E. Cecelski, *Energy Strategies for Developing Nations* (Johns Hopkins Univ. Press for Resources for the Future, Baltimore, 1981), and most of the key results discussed here are derived from the joint work of the four authors of that book. Research for the book was carried out under a grant from the Ford Foundation. An earlier version of this article was prepared for *Improving World Energy Production and Productivity, Proceedings of the 1982 World's Fair International Energy Symposium II* (Ballinger, Cambridge, Mass., in press). We wish to express our appreciation to John E. Jankowski, Jr., for support in writing this article.