Chapter 1

Overview

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Overview

SUMMARY

Developing countries need energy to raise productivity and improve the living standards of their populations. Traditionally, developing countries have addressed their energy needs by expanding the supply base with little attention to the efficiency of energy use. This approach is now, however, raising serious financial, institutional, and environmental problems. The magnitude of these problems underlines the need for improving the efficiency with which energy is currently used and produced in developing countries.

OTA finds that there are major opportunities—drawing on currently available or near-commercial technologies-for improving efficiencies throughout the energy systems of developing countries. These technologies promise to save energy, diminish adverse environmental impacts, reduce life cycle costs to consumers, and lower systemwide capital costs. Despite these advantages, efficient technologies may not be rapidly adopted unless technology transfer is improved and policies and procedures in donor agencies and the developing countries themselves are designed to remove impediments to their adoption. There are already promising signs of greater attention to removal of such barriers, but much remains to be done.

The way in which developing countries meet their energy needs directly relates to a number of U.S. policy concerns. International political stability depends on steady broad-based economic growth in the developing countries, which in turn requires economic and reliable energy services. The developing countries are of growing importance in global energy markets and global environmental issues: these countries are projected to account for over one-half of the increase in global energy consumption over the next three decades with corresponding increases in their emissions of carbon dioxide, a major greenhouse gas. Sharply rising demand for oil from the developing countries contributes to upward pressure on international oil prices. Developing country debt, often energy related, affects the stability of U.S. and international banking systems. At the same time, developing countries offer the United States important trade opportunities in their large and expanding markets for energy technologies.

The United States has a number of programs influencing the diffusion of energy efficient and renewable energy technologies in developing countries, The United States could increase its influence by providing greater leadership in technology transfer, including research, development and demonstration, information dissemination, and training. The United States could also promote the adoption of more energy efficient technologies by supporting policy changes in both lending agencies and developing countries. Finally, the United States could set a good example of energy efficient behavior at home.

ENERGY ISSUES IN DEVELOPING COUNTRIES

Commercial energy consumption in developing countries is projected to triple over the next 30 years, driven by rapid population growth and economic development. Even assuming continued declines in fertility rates, the population of the developing world will increase by nearly 3 billion-to almost 7 billion-over the next three decades, stimulating a sharp increase in demand for energy services. Securing higher living standards for this growing population requires rapid economic growth, further increasing the demand for energy services. This demand is augmented by structural changes inherent in the development process, especially urbanization; the building of the commercial, industrial and transportation infrastructure; and the substitution of commercial for traditional fuels. Demand is further augmented by the rapid rise in demand for consumer goods—lights, refrigerators, TVs—stimulated by their lowered real cost, improved availability, and frequently subsidized energy prices. Even though per capita commercial energy consumption will remain well below the levels of the industrial countries, the more rapid population and economic growth in developing countries means that their share of global commercial energy consumption would rise-horn 23 percent today to a projected 40 percent in 2020.

Efforts to supply energy on this scale face serious financial, operational, and environmental constraints. Capital intensive electricity generating stations and petroleum refineries already account for a large part of all public investment budgets in developing countries, with electric utilities taking the lion's share. Yet, annual electricity sector investments would have to double to provide supplies at projected growth rates. A large part of the investment in energy facilities and in the fuel to operate them must be paid for in foreign exchange, already under pressure in many countries. In addition, there is often a shortage of local currency to pay for energy development due to inadequate revenues from existing operations. The high cost of developing national energy infrastructures and of importing energy to support growing energy demands could, in some cases, slow overall economic growth.

The energy supply sector in many developing countries also experiences a wide range of operational problems. These problems raise questions about the ability of energy supplies to expand rapidly even if financial resources were available. Finally, the environmental impacts of rapid supply expansion could be substantial. The production and use of both commercial and traditional fuels contribute to the accelerating rates of environmental degradation now occurring in many developing countries. Energy trends in developing countries are also of global environmental concern. These countries are already important contributors to greenhouse gas emissions from fossil fuel use, accounting for one-quarter of annual global energy sector carbon dioxide emissions. Deforestation and the emission of other greenhouse gases, such as methane and NO_x, further raise the share of developing countries in total global greenhouse gas emissions. Although per capita levels of greenhouse emissions from energy use are much lower than in the industrial countries, the developing countries' rapid population and economic growth will increase their share of total emissions in the future.

The magnitude of these problems underlines the need for improving the efficiency of energy use and production in developing countries. Improved efficiencies can moderate the expansion of energy systems while still providing the energy services needed for development. Energy efficiencies vary in the developing world but, on average, appear to be much lower than in the industrial countries.

While the wide differences in technical efficiencies in reasonably standardized operations, such as cooking, steel making, and electricity generation, suggest that dramatic improvements in efficiencies are possible, factors other than technology also play an important role in improving efficiencies. Thus, an energy system may seem technically ''inefficient" when, in many cases, users and producers are acting rationally given the framework of resources, incentives, and disincentives within which they make their decisions. One of the reasons that poor households use inefficient traditional fuels is that they lack the financial means to buy more efficient technologies and fuels. Many industrial processes are inefficient due to antiquated machinery and erratic fuel supplies of uncertain quality. The policy environment that determines this pattern of incentives and disincentives is crucial to the adoption of new technologies.

The way in which developing countries provide their energy services is important to the United States for a number of reasons:

- International Political Stability. Steady broad-based economic growth in the developing countries is a prerequisite for long-term international political stability. The provision of economic and reliable energy services plays a key role in securing such economic growth.
- Humanitarian Concerns. Humanitarian and equity concerns have long been a core element of U.S. foreign relations with developing countries. Helping developing countries to meet their energy needs can play an important role in assisting low income groups.
- Trade and Competitiveness. With the large trade deficits of recent years and the growing internationalization of the economy, the United States has little choice but to pay close attention to export markets. Many of these will be in the developing countries. The electricity sector of developing countries alone is projected by the World Bank to need a capital investment of nearly $750 billion during the 1990s. Similarly, there will be large markets in consumer products such as automobiles, refrigerators, and air conditioners. The United States faces intense competition in the increasingly important markets for energy efficient manufacturing processes and consumer products.
- Global Environmental Issues. Regional and global environmental issues such as acid rain,

ozone depletion, and global warming are strongly related to energy production and use. These issues are becoming of increasing concern to developing and industrial countries.

- Global Oil Markets. The World Energy Conference projects that developing countries will account for about 90 percent of the increase in world oil consumption between 1985 and 2020. This will put significant upward pressure on oil markets and could lead to both higher prices and greater volatility, with corresponding impacts on U.S. inflation, balance of trade, and overall economic performance.
- Global Financial Markets. High levels of developing country indebtedness (a significant portion of which was incurred in building the energy sector) affect global capital markets and the global banking system. This contributes to the instability of the U.S. and international money and banking systems.

IMPROVING EFFICIENCIES IN RESIDENTIAL, COMMERCIAL, INDUSTRIAL, AND TRANSPORTATION ENERGY USE

The Potential

This OTA study shows that it is possible to improve the low technical efficiencies with which energy is produced, converted, and used in developing countries through the adoption of proven cost effective technologies. On the demand side, these include efficient lights, refrigerators, cars and trucks, industrial boilers, electric motors, and a variety of new manufacturing processes for energy intensive industries such as steel and cement. Moreover, numerous technologies at various stages of RD&D and commercialization can further increase the efficiency of delivering these energy services. Widespread adoption of these technologies could achieve substantial energy savings, while still providing the energy services needed for development. Capturing these energy savings would help environmental quality, and ease the burden of high import bills for the many developing countries that import most of their energy supplies.

Improved technologies are not limited to the modem urban sectors of developing countries. Technology can also provide energy services for the vast majority of the population of the developing world that lives outside or on the margin of the modem economy. In rural and poor urban households, more efficient biomass stoves could both reduce fuel use and cut back the hazardous smoke emissions that are a potentially significant contributor to ill-health among women and young children. Simple motor driven systems for pumping water or grinding grain can dramatically reduce the burden on women who now spend several hours per day performing these physically demanding tasks. Energy efficient pumps, fertilizers, and mechanical traction (e.g., rototillers and small tractors) can improve agricultural productivity. Technology also can boost the efficiency, quality, and productivity of traditional small scale industry, which accounts for one-half to three-quarters of manufacturing employment in many developing countries and is an important source of income for the rural and urban poor.

The Example of Electricity

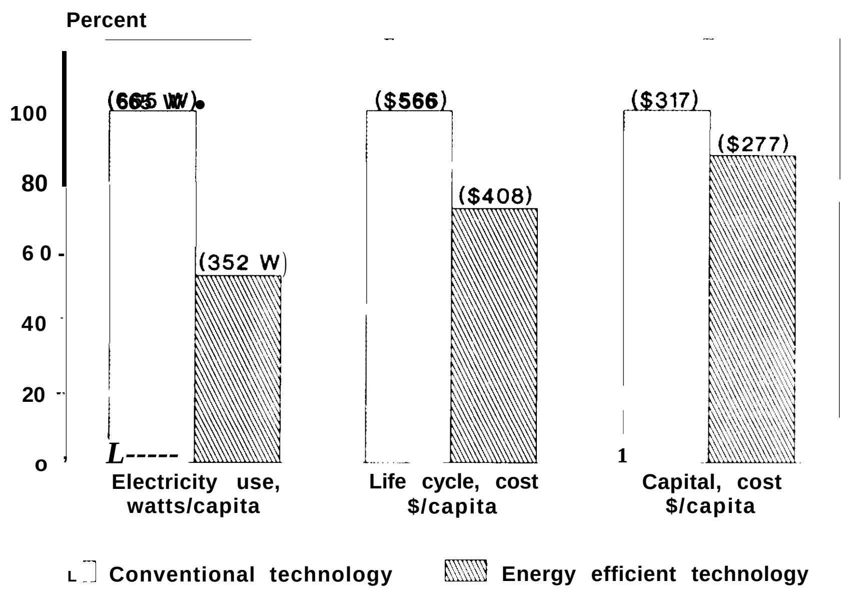
The large potential for energy efficient technologies can be illustrated in the electricity sector. Electricity demand is rising rapidly, by 10 percent or more annually in many developing countries. Matching this increase in demand with corresponding increases in electricity generation may not be feasible for many developing countries due to their high indebtedness and already strained budgets. Even if it were possible, such rates of increase would imply a substantial increase in electricity's share of development budgets, to the detriment of other important development expenditures.

This OTA study, based on conservative estimates,[1] shows that for a wide range of electricity using services-cooking, water heating, lighting, refrigeration, air conditioning, electronic information services, and industrial motor drive--overall electricity savings of nearly 50 percent are possible with currently available[2] energy efficient technologies (see figure 1-1). Further, these technologies would provide financial savings to individual con-

[1] See app. A for details of assumptions and calculations.

[2] The one technology included in the scenario that is not currently generally available is the high efficiency refrigerator. Refrigerators with efficiencies as high or higher have been demonstrated and are for sale in small lots, however.

Figure 1 -l—Electricity, Life Cycle Cost, and Capital Cost Savings of High Efficiency End Use-Equipment in the Electric Sector



This figure shows that society-wide (including both utility and end user investments) electricity savings of about 47 percent, life cycle cost savings of 28 percent, and capital cost savings to society of about 13 percent are possible by investing in energy efficient equipment rather than the standard equipment most commonly purchased today. The assumed mix of energy services and activity levels corresponds to a Western European or American standard of living. Primary energy savings are about 2 percent less than suggested here because of the substitution of gas cooking for part of the electric cooking in the high efficiency case.

The estimates provided here are probably substantial underestimates of the capital and life cycle cost advantage of energy efficient equipment. The costs of energy supply were substantially underestimated--system performance, for example, was assumed to be higher than that achieved in virtually any full service developing country power system. On the end use side, costs were generally overestimated and savings underestimated. For example, many lowermost energy efficient alternatives-such as insulation for buildings to reduce heat gain and consequent air conditioner loads-were not included; synergisms between energy efficient equipment were not considered (e.g., high efficiency equipment gives off less heat, reducing the load on&r conditioners); and the total cost of these improvements was allocated to efficiency alone whereas many of the benefits—and often the basis for making the investment-are unrelated to energy use (e.g., users may invest in improved motor drives to better control manufacturing processes, and at the same time realize substantial energy savings). Finally, various external costs such as that of the pollution associated with energy supply equipment were not included.

Details of the calculation and a sensitivity analysis are provided in appendix A at the back of this report.

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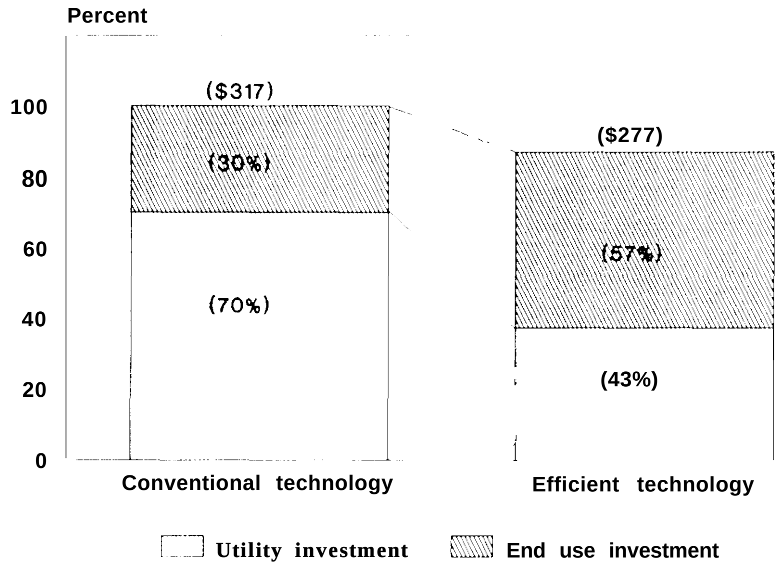
SOURCE: U.S. Congress, Office of Technology Assessment, 1992.

sumers over the lifetime of the equipment of more than 25 percent.

It is commonly believed, however, that widespread adoption of energy efficient technologies will not occur, in large part because of their perceived high capital costs. This is an important consideration for poor, heavily indebted countries. The argument that the capital costs of energy efficient equipment are too high depends critically, however, on the frame of reference for considering capital costs. This OTA study shows that when all the systemwide financial costs are accounted for, energy efficient equipment usually can provide the same energy services to the Nation at a lower installed capital cost than less efficient equipment (see figure 1-1). The estimates presented here suggest that over 10 percent of the initial capital investment in the

Figure 1-2—Allocation of Capital Investment Between End User and Utility



This figure shows that the capital costs of high efficiency end use equipment fall largely on the end user (but the end user still saves money over the equipment's lifetime) while the required capital investment by the utility drops substantially (and the total capital investment to society is reduced--figure 1-1). This is the basis for the belief that end use equipment has a higher initial capital cost-it does cost more for the end user. Redistributing these capital costs so as to reduce the burden felt by the end user (who is typically extremely sensitive to initial capital costs) could thus allow greater penetration of these highly advantageous technologies.

SOURCE: U.S. Congress, Office of Technology Assessment, 1992.

electric sector could be avoided by investing in currently available high-efficiency equipment. With projected "business as usual" investments in the electric utility supply sector in developing countries expected to total $750 billion during the 1990s, energy efficiency could save substantial capital.

Capital could be saved because the higher initial cost of efficient end use equipment is usually outweighed by the savings realized from building fewer power plants. Taking advantage of opportunities to install energy efficient equipment is particularly important in developing countries because of the rapid growth in stocks of energy using equipment and the high share of total investment budgets devoted to increasing energy supplies,

The perception that energy efficient equipment has a high capital cost results from the way institutions account for capital costs of energy supply and end use equipment. Consumers who purchase end use equipment see the increase in capital cost of more efficient designs, but not the decrease in capital costs as fewer power plants are built in order to provide a given level of energy service.

Though energy efficiency could result in substantial capital savings, the allocation of investment between energy supply and end use would need to change dramatically. Capital investment in electricity supply (borne by the utility) would be cut nearly in half while that in end use equipment (currently borne by the end user) would increase by about two-thirds (see figure 1-2). Such a reallocation of expenditure patterns is likely to impede adoption of efficient end use equipment. To overcome these barriers, institutional changes are needed to enable decisionmaking on a systemwide basis, and to initiate innovative mechanisms that focus the financial resources of utilities on the adoption of efficient end use equipment. A powerful tool for achieving such a systems approach is Integrated Resource Planning (IRP--see ch.3), in which energy efficiency investments are explicitly included as an alternative to capacity expansion. This methodology

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is supported by many utilities and public utility commissions in the United States.

Impediments to the Adoption of Energy Efficient Technology

Despite the multiple benefits of these energy efficient technologies, many have not yet been widely used because of pricing policies, a variety of market failures, institutional impediments, and technical barriers.

Pricing Policies

Government pricing policies frequently discourage the adoption of energy efficient equipment. Energy pricing policies have several objectives: the efficient allocation of resources, social objectives, reasonable returns to producers, substitution between fuels for national security or environmental reasons, and industrial competitiveness. Social objectives, including the desire to ensure that household fuels are price-stable and affordable by the poor, play a major role in pricing policies in developing countries. Economic objectives, notably the desire to encourage key strategic development sectors, are reflected in policies that promote rural electrification or that keep diesel prices low. As a result, energy prices in developing countries, particularly for electricity and-in many oil-producing countries-for petroleum-based fuels, are often set by the government at well below market value. For example, the average cost of electricity to consumers in developing countries is just 60 percent of the cost of producing it.

Policies that keep key energy prices low, however, can bias the choice of technology away from energy efficiency. Low prices also may result in revenues that cannot cover the costs of supplying the energy, leading to a decline in quality and availability of energy supplies. Though designed to help the poorer part of the community, energy subsidies may in fact largely benefit the more affluent classes who are the heaviest users of commercial fuels.

Market Failures

The diffusion of technology within the developing countries is also impeded by a variety of market failures. In the residential/commercial sector, for example, consumers are extremely sensitive to the frost costs of equipment, and in many cases are not even the purchasers of the equipment they use. The contractor who builds the office or the landlord who rents the housing often purchase the appliances used in the building and base their choice of appliance on lowest first cost rather than life cycle operating costs. The tenants, not the owners, must pay the cost of operating this inefficient equipment.

In the industrial sector, plant managers' efforts to improve energy efficiency can be impeded by frequent brownouts or blackouts; lack of foreign exchange to purchase critical components not available locally; and lack of skilled engineers and managers. Each of these factors can be particularly disruptive to the utilization of energy efficient technologies.

Moreover, energy efficiency is often of secondary interest to industrial firms. Energy is just one, and often a minor, component of overall corporate strategy to improve profitability and competitiveness. Energy must compete with other factors—the financial return, the quality and quantity of product produced, the timeliness and reliability of the production equipment, and the flexibility of the equipment—when investment choices are made and scarce time of skilled manpower allocated. In many countries, local industries are protected from competition and therefore have less incentive to lower costs through the introduction of energy efficient equipment.

Further, because of poor transport infrastructure, scarcity of capital, and limited ability to bear risk, manufacturing plants are often much smaller in scale than their industrial country counterparts. Small scale manufacturing plants, however, are typically less energy efficient and require greater capital investment per unit output to realize the energy savings that can be achieved in large plants.

In the transport sector, higher first costs of energy efficient autos, trucks, and motorcycles often deter consumers from buying them, despite being cost effective on a life cycle basis. The available infrastructure may strongly influence the choice of technology as well as the efficiency of its use. Poor land use planning or ineffective controls, for example, may result in urban sprawl, which in turn leads to reliance on personal rather than mass transport. A high degree of reliance on personal transport can then cause congestion, lower average speeds, and reduce efficiencies, subsequently increasing demands for capital-intensive highways.

Supply Biases

In the public sector, the multilateral development banks and bilateral donor agencies influence the amount and type of technology transferred through their lending and technical assistance activities. The bulk of technology transfer activities in these agencies has been directed to large scale supply oriented projects—notably major electricity generating facilities including hydroelectricity. The activities and approach of these agencies do not appear to be well adapted to the special needs of transferring conservation and small renewable technologies. The private sector, too, is accustomed to large scale conventional supply projects.

Technical Barriers

The energy efficient equipment developed in the industrial countries may not be suited to conditions in developing countries. Considerable adaptation may be needed, but manufacturers may not have adequate funds available for the necessary RD&D-especially when supplying companies are small and developing country markets are limited and expensive to access. There are also technology gaps. Technologies important to the rural populace, the majority of the population in developing countries, get relatively little attention.

Policy Responses

A number of policies might be adopted throughout the technology transfer process to help overcome these barriers. These include: increased attention to technology adaptation; increased training in energy efficient end use or improved supply technologies; reforming energy pricing policies to reflect the full costs to the Nation of supplying energy; taxation of inefficient equipment; improved information to consumers; financial incentives (e.g., tax relief or low-cost loans) to encourage production or purchase of energy efficient equipment; and efficiency standards. Reforms in energy pricing policies can encourage the purchase of energy efficient equipment, but prices alone are usually insufficient to overcome the strong nonprice and institutional barriers to improved efficiency. Energy efficiency standards, innovative financial mechanisms, or other policies might be used to reinforce price signals.

Changes in regulation of the electricity supply industry to create closer links between suppliers and users could overcome a major institutional barrier to the adoption of efficient appliances. Decisionmaking in the key electricity sector is strongly biased in favor of supply expansion and typically does not take a ‘‘systems’ view (see ch.3) of electricity service. One way to encourage this to happen is through the use of Integrated Resource Planning (IRP--see ch.3) in utility decisionmaking. IRP includes both energy efficiency and energy supply options in decisions about how to provide energy services. This contrasts sharply with current procedures that focus on supply options only. Though straightforward in concept, IRP can, however, be difficult to implement. Supporting changes in utility regulation would be required, as well as substantial complementary education, training, demonstration, and monitoring of results.

IMPROVING ENERGY SUPPLY EFFICIENCY

Even with substantial end use efficiency gains, growing populations and increased economic activity in developing countries will require expansion of energy supplies. Here, too, available technologies can improve the efficiency of supplying and converting energy into useful forms and of developing domestic resources. Improved technologies also can moderate the environmental effects of energy production.

Conversion Technologies

A number of technologies have the potential to improve the efficiency and performance of the energy conversion sector. Given low operational efficiencies in the electricity sector, technologies for plant rehabilitation, life extension, system interconnection, and improvements in transmission and distribution systems often offer higher returns to capital investment than do new plants. Improvement of existing systems would have the added advantage of putting into place a more efficient framework for future capacity expansion. By the same token, failure to improve the existing system will be detrimental to efficient supply expansion in the future, regardless of technology.

For capacity expansion, fluidized-bed combustion (FBC) has greater tolerance for the low-quality coal often used in developing countries and can reduce SO_2 and NO_x emissions. Advanced gas turbines, particularly when used in a combined-cycle or steam-injected mode-promise to be one of the most attractive new technologies for electricity generation in the developing world. Operating efficiencies can be high, and because they are small and modular with short construction lead times, gas turbines are also suited to private power producers with limited capital.

The relatively small, modular, and safer nuclear power technologies under development may extend the market for nuclear power in developing countries. Their cost and performance characteristics, however, are uncertain. The technical skill requirements, relatively high cost, and ongoing concerns about waste disposal may also continue to limit the use of nuclear power in developing countries. Another important concern is the potential for nuclear weapons proliferation, which has been greatly heightened by the recent disclosure of the relatively advanced status of Iraq's nuclear weapons program.

Development of the extensive hydroelectric resources in many countries has already provided large amounts of power. Large scale hydroelectric development remains problematic, however, due to the economic and social impacts of large scale projects, and, in many cases (as in Africa), initial lack of markets. Smaller scale hydro could overcome some of these problems.

Stand alone renewable, such as wind turbines and photovoltaics, are now cost competitive with diesel generators and grid extension in many situations. Although the role of renewable remains very limited today, it could expand substantially in the future as their costs continue to decline. These technologies are of particular importance in providing high-quality energy sources to rural areas. Geothermal energy is also available for a select few countries. A number of technologies offer promise for the conversion of biomass into improved liquid and gaseous fuels, if cost effective and sustainable biomass supplies can be assured (see below). Increased conversion of biomass is particularly promising where there are captive residues, such as in agroindustry or the forest products industry. Much more efficient use of the biomass now consumed is possible as well, through modem bioenergy conversion and utilization technologies.

Cost effective retrofits could improve refinery efficiencies, and new technologies could permit small scale and relatively low cost conversion of methane to methanol.

Primary Energy Supplies

China, India, and several other countries have large coal resources. China and India, the two biggest users, plan to expand their coal use considerably. Coal as presently produced and used in these countries has severe environmental impacts such as emissions of acid rain precursors and greenhouse gases, and mining damage to the land and water. Large scale use also poses major logistical problems when coal fields are distant from major users. Substantial improvements in coal mining in India and China could be achieved through increased use of high-performance mining and beneficiation technologies currently used in other countries.

The developing world possesses only limited crude oil reserves, with a reserves/production ratio of 26 years compared with a worldwide ratio of 43 years. These reserves are concentrated in a few countries, including Mexico and Venezuela. One-half of the developing countries have no discovered recoverable reserves. The industry consensus is that the oil reserves likely to be proved in developing countries will be relatively small. The development of such fields, while traditionally unattractive to the major oil companies, is important for the developing countries themselves-especially the poorer ones. A number of recent technical developments in oil exploration and development may reduce risks and costs, thus making small field development more attractive than before, and facilitating the entry of smaller oil companies in developing countries.

These technologies also could aid exploration for natural gas, a fairly versatile fuel and one that is environmentally less damaging than coal or oil—both locally and globally. The reserves/production ratio for natural gas in the developing world is about 88 years-much more favorable than crude oil. Natural gas resources are more widely dispersed among the developing countries than oil. In several countries, large amounts of developed natural gas are currently flared because of the lack of infrastructure and organized markets.

Biomass is an important energy resource that could be better used in most countries. In the technical arena, several advances have been made to improve plant productivity in recent years. Fast growing species, and intercropping and multiple species opportunities have been identified, physiological knowledge of plant growth processes has been improved, and there have been breakthroughs in manipulation of plants through biotechnology. Crop residue densification increases their energy content and in some cases can thus reduce transport and handling costs.

The Benefits

These new energy supply technologies offer numerous potential advantages:

- Modular, Small Scale, and Short Lead Times. Several of these new supply technologies, notably advanced gas turbines and many types of renewable energy technologies, are small and modular, and can therefore better match demand growth both in size and construction time. Conventional coal-fired power plants or petroleum refineries generally are constructed in very large units with long lead times-as much as 10 years or more. The large incremental size of energy supply systems makes it difficult to match supply to demand. The long lead times result in large quantities of capital being tied up in a project for years before the project becomes productive. Both of these factors raise costs and increase risks.
- Plant Reliability and Performance. Developing countries experience frequent service curtailments, including blackouts, brownouts, and sharp power surges. Unreliable service means that industries and offices are unable to operate, production is lowered, and raw materials are wasted. Losses can be considerable. Lost industrial output caused by shortages of electricity in India and Pakistan is estimated to have reduced Gross Domestic Product (GDP) by about 1.5 to 2 percent. Many consumers—residential, commercial, 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. Improved operating and maintenance procedures as well as a variety of new technologies could improve plant reliability and performance.
- Rural Energy. Most of the population of developing countries live in rural areas, the great majority in poverty and without access to the services that could increase their productivity and improve their standard of living. Several of the smaller scale technologies (modern biomass energy and decentralized renewable) can bring high quality fuels to rural areas and thus promote rural development and employment.
- Environmental Benefits. Different types of energy supply may have different environmental impacts over various time periods. For example, a coal-fired power plant generates air emissions today with both near-term acid rain and potentially longer term global warming impacts, while a nuclear plant has the potential (though the probability is low) for catastrophic release of radiation at any time. This, plus the general lack of knowledge of the environmental impacts, makes the comparison of different types of energy supply difficult.

  With these reservations, this analysis suggests that among conventional systems, natural gas generally has the least adverse environmental impacts. Increased emphasis on natural gas could reduce land disturbances, air and water pollution, and occupational health hazards compared with coal, and could avoid some of the problems of large hydro and nuclear. Modem biomass systems (properly handled) could also reduce environmental impacts compared to coal or other conventional fuels. Decentralized renewable generate less air pollution, and, because of their small scale incremental nature, may avoid some of the environmental problems of large scale energy projects. There is, however, little experience with large scale use of decentralized technologies to serve as a basis for firm decisionmaking.
- Foreign Exchange Saving. New technologies that develop local energy resources will reduce energy imports-which currently account for over 50 percent of export earnings in several of the poorest countries.
- Employment. Decentralized renewable could stimulate employment. Even though developing countries would, at least initially, import much of the technology, renewable need installation and servicing that could create local jobs. Production of biomass energy can also create rural employment.

Impediments to Adoption

In practice, a variety of difficulties could impede use of these energy supply technologies. Many of the problems in the energy supply sector are not due to a lack of adequate technology, but rather to the institutional structure and procedures. The operating efficiency of electricity generating equipment and oil refineries in many developing countries is often substantially below that of industrialized countries with similar technology. A number of factors lie behind this poor performance: official interference in day-to-day management of the utilities; overstaffing but shortages of trained manpower; lack of standardization of equipment; limited system integration and planning; distorted pricing structures; obligations to provide parts of the population with electricity at less than cost; shortages of foreign exchange to buy spare parts; and regulatory frameworks that discourage competition. The effective deployment of technology will therefore depend on addressing these related financial, policy and institutional issues.

Institutional issues are also important for accelerated oil and gas development. Despite promising geological prospects, hydrocarbon exploration activity (density of wells drilled) in the developing countries is much lower than the world average, and is concentrated in countries where resources have already been developed. In most developing countries (with the exception of a few large-population countries, such as Mexico and Venezuela), investment in petroleum exploration and development is carried out almost exclusively by international oil companies. Thus, the fiscal and contractual arrangements between country and company need to include appropriate incentives. These incentives have traditionally been biased in favor of large, low cost fields and may need to be changed to encourage the development of small higher cost fields. Gas development faces additional obstacles. Unlike oil markets, gas markets must be developed concurrently with the resource, adding to the start-up costs and complexity of gas projects. In the past, this has been a formidable obstacle, but new technologies, such as small high-performance gas turbines, could greatly help market development. Even so, gas sold in local markets does not directly generate the foreign exchange needed to repatriate profits to foreign investors.

The introduction of modem biomass energy technologies encounters different problems. These include inadequate research, development, and demonstration; direct or indirect subsidies to other energy supplies that may discourage investment; high land and infrastructure (notably roads) costs; and lack of credit, which may not be as readily available for modern biomass supply systems as for other more conventional supplies such as coal- or oil-fired electricity.

The development of large scale, cost effective, sustainable biomass feedstocks also faces uncertainties. Data on the extent of forest area and the annual increment of forest growth are sparse and unreliable, and little is known about the impacts of intensive biomass development on soils and other environmental assets. Improvements in forest management are notoriously difficult to achieve, and the introduction of high-yield energy crops together with the necessary improvements in agricultural practice will require long-term sustained efforts. Finally, policies to promote bioenergy could create competition for land between energy crops for the rich or food crops for the poor.

ISSUES AND OPTIONS FOR THE UNITED STATES

Developing countries have been slow to adopt improved energy end use and supply technologies, despite the potential advantages, due to the technical, institutional, and economic barriers described above. Developing countries are, however, demonstrating interest in seeking alternative ways of meeting the demand for energy services, despite the difficulties of changing entrenched systems. Increased attention is being given, for example, to politically sensitive questions such as energy price reform, improved management, and operations efficiency in state-owned energy supply industries. Several developing countries are taking steps to encourage private investment in electricity and in oil and gas. Many countries have developed capable energy resource and policy institutions. Progress is also being made on the environmental front. Although much of the current environmental focus of developing countries is on local rather than global conditions, these countries also participate in international resource and environmental protection policy discussion and treaties.

There is also evidence of change in donor institutions. The bilateral donor agencies and the multilateral development banks (of which the most influential is the World Bank) are beginning-often under pressure from Congress and nongovernmental organizations —to incorporate environmental planning into their projects, to develop energy conservation projects, and to encourage a larger role for the private sector. This momentum for change offers a timely opportunity for U.S. initiatives.

A substantial number of U.S. agencies already has programs that influence the diffusion of improved energy technologies in developing countries. These include the Agency for International Development (AID), the Trade and Development Program, the Departments of Energy, Commerce, and the Treasury, the Overseas Private Investment Corporation, the Export-Import Bank, the Small Business Administration, and the U.S. Trade Representative. The United States exercises additional influence through membership in international organizations, notably the World Bank and the regional development banks and the United Nations programs. A number of U.S. based industry groups and nongovernmental organizations is also active in this field. These agencies and organizations cover a wide range of technology transfer and diffusion activities—-research, development, and demonstration; project loans and grants; education, training, and technical assistance; information services; policy advice; support for exports and private investment; and others.

In one sense, the United States already has a considerable policy infrastructure in place for promoting energy technologies in developing countries. This policy infrastructure has, however, focused on supply development, including renewable in recent years, and is only now beginning to accept efficiency as an important theme. Further, given the large number of programs and activities, the question arises of their cohesion and cooperation to ensure maximum effectiveness. Efforts have been made to coordinate at least some aspects of the work of the different agencies and organizations through both formal and informal channels. For example, in the Renewable Energy Industry Development Act of 1983, Congress initiated a multiagency committee called the Committee on Renewable Energy Commerce and Trade (CORECT) to promote trade in U.S. renewable energy technologies. Now could be a good time to examine the extent to which this model of coordination could be applied to other relevant areas, such as energy efficiency and the environment.

Despite the large number of programs and wide range of activities, the current level of U.S. bilateral aid for energy is small. USAID grants and other assistance in the energy sector total about $200 million per year compared with multilateral development bank (MDBs) annual energy loans of $5 billion. The small scale of U.S. bilateral assistance for energy suggests that the sums available are currently and will continue to be used to greatest effect by:

- using limited U.S. bilateral grant monies to promote technical assistance and institution building;
- including technology transfer in broader bilateral policy discussions, such as debt negotiations;
- influencing the activities of the multilateral development banks;
- cooperating with other bilateral donors, lending agencies, and private voluntary organizations (PVOs); and
- encouraging a wider role for the private sectors of both the industrial and developing countries.

In this context, the analysis presented below leads to a series of broad policy options for Congress to consider. In particular, the following policy areas merit priority consideration:

- devoting additional attention to energy efficiency, the environmental impacts of energy developments, and the energy needs of the rural and urban poor in current bilateral and multilateral lending programs;
- encouraging energy price reform in developing countries to stimulate the adoption of energy efficient equipment and to help finance needed supply expansion;
- providing technical assistance to support Integrated Resource Planning (IRP) and associated regulatory reform to guide investments in energy supply and end use projects, particularly in the electricity sector-this could help developing countries secure the savings potential illustrated in figure l-l;
- providing technical assistance, information, and training in other potentially significant areas, such as environmental protection, appliance and industrial equipment efficiency, utility management, and transportation planning;
- assisting in institution building, especially for technology research, development, adaptation, testing, and demonstration;
- encouraging private sector (from both the United States and developing countries) participation in energy development;

- expanding U.S. trade and investment programs—U.S. energy related exports and investment have traditionally been an important channel for energy technology transfer to developing countries;
- making sure that the United States sets a good example for the rest of the world in energy efficiency and environmental protection.

Congress has already taken action in several of these areas—support for IRP, efficient energy pricing, and consideration of environmental impacts of projects. In these cases, the primary question may be the effectiveness of existing interventions rather than the need to take additional action.

Efficient energy technologies often reduce systemwide capital investment as well as life cycle operating costs. Under these conditions, redirecting capital funds from supply expansion to energy efficiency projects in the MDBs and other financing institutions would free resources for additional investment in energy services or other pressing development needs, Even if all these savings were reinvested in the energy sector, however, the rapid rise in demand for energy services will require substantially more investment than that projected to be available. The MDBs and other bilateral and multilateral financial institutions will need, therefore, to continue providing high levels of support, while at the same time supporting actions (e.g., debt negotiations, macroeconomic reform, and privatization) to encourage increased private sector participation.

Several of the options for accelerating the adoption of energy efficient technology imply an increase in bilateral assistance. While increases in bilateral aid run counter to efforts to control budget expenditures, the share of bilateral aid (particularly in AID) devoted to energy is low in relation to: total bilateral expenditures; the share of energy in the aid efforts of other donors; and the potential importance of developing countries as markets for U.S. exports of improved energy technologies. Some redistribution of expenditures could be considered. The geographical distribution of existing AID energy expenditures, concentrated in the Near East, may not adequately reflect the totality of U.S. policy interests.

The diffusion of improved energy technologies in developing countries and the ways in which the United States can accelerate this diffusion is a complicated process involving a number of agencies and institutions. The principle behind these actions is, however, simple: energy is not used for its own sake, but for the services it makes possible. If energy policy concentrates on the best way to provide these services, rather than automatically encouraging increased energy supplies, opportunities expand dramatically. Though it is not easy for institutions designed for supply expansion to change to a service orientation, their interest is growing and the stakes are high. This analysis provides strong evidence that such a change could release billions of dollars that could provide energy services to those who would otherwise be without, or to finance the many other economic and social goals of developing countries. The United States can make an important contribution to this change in policy through its bilateral programs, its influence on MDB programs, and through cooperation with other donors. In so doing, the United States could develop closer partnerships with the developing countries themselves, who are increasingly looking for new, more efficient ways to meet the rapidly growing demand for energy services.