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Energy Technology for Developing Countries: Issues for the U.S. National Energy Strategy

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December, 1989

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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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Preface

On June 28 and 29, 1989, the U.S. Department of Energy (DOE) organized a meeting with representatives of the national laboratories to discuss laboratory input into a DOE exercise to develop a National Energy Strategy. One of the results of this meeting was a request that a group of laboratories join together to produce this report, dealing with energy technologies for developing countries. This report constitutes one of the national laboratory inputs into the National Energy Strategy.

Participants from seven national laboratories met together on several occasions and have contributed to this report. The laboratories and the team members who have participated in preparing this report are:

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Energy Technology for Developing Countries:
Issues for the U.S. National Energy Strategy

1. Executive Summary

1.1 Introduction

Energy is a critical input to the economic system of all nations. Issues involving energy are of particular importance to developing nations. Efficient energy production, use, and allocation can contribute to economic development in significant ways. Inefficient energy systems can be a drain on capital and can retard sustainable development.

This study explores the role of energy among developing countries to better understand how these energy issues impact the United States. We conclude that the energy choices made by developing countries already have major impacts on the United States. These impacts will grow in the coming decades. We also note that present efforts to provide energy assistance to developing countries are very limited, compared with the magnitude of the problems being faced. We are convinced that improved energy technologies, as well as training in their use, are and effective mechanisms of technology transfer, are an important ingredient in solving the problems.

1.2 Developing Countries and a U.S. National Energy Strategy

Developing nations have become a major participant in the world energy economy. As a result, the energy choices made by these nations will be increasingly important in determining the future stresses on the international oil market and the global climate. Developing countries also comprise rapidly growing potential markets for U.S. technologies. Their economic and political stability is important to U.S. security. Energy decisions play a particularly important role in overall well-being and development of low income nations as energy is a major input to industrial activities and rural development, and requires a major commitment of capital in the economy. Finally, the U.S. has traditionally sought to improve the living conditions of those in less fortunate nations; energy assistance is a key component of such humanitarian support.

The U.S. National Energy Strategy should therefore be concerned with the relationship of critical energy choices made by developing nations to U.S. objectives. Better technologies for providing energy services and for converting and using energy more efficiently, cleanly, and economically are powerful tools for achieving both U.S. and developing nation objectives. Every nation is unique in its conditions for making energy choices, and technologies developed for U.S. markets may not meet the needs in many developing nations, at least not without significant modifications.

1.3 Energy and Developing Countries

In 1970 the developing countries of the world consumed about 16 percent of the world's commercial sources of energy; currently they consume about 25 percent. Most analyses of future energy demand in the developing world show continued rapid growth, both in absolute terms and relative to the industrialized world.

This energy growth has not been without substantial problems. There are continuing shortages of energy for productive uses in many parts of the developing world. Energy is used very inefficiently in all sectors. Power losses are typically high, power generation is often inefficient, industrial activities often use outmoded technologies or are poorly maintained, buildings and appliances use considerably more energy than necessary, and transport needs are growing rapidly but not efficiently. Rural energy needs are often inadequately met, and biomass is often used in

ways and quantities that may not be sustainable. Access to efficient technologies for energy supply, conversion, and end-use is limited. Capital for the power sector, for exploration, and for investment in efficient end-use technologies is inadequate. A recent study by the U.S. Agency for International Development (AID) estimated a need for $125 billion per year for new generating capacity, but an availability of only $50 to $60 billion per year. This study noted that substantial efficiency gains could reduce the capital requirements considerably, but that capital would still remain insufficient to meet needs.

The mix of energy problems faced by developing nations varies considerably among different regions and countries. Nonetheless, because of its primary role in fueling economic development and providing for welfare of inhabitants, energy constitutes a central issue of sustainable economic development. Both energy, and especially energy services, are needed. Inefficient use of energy or application of outmoded technologies is injurious to development. Improved energy technologies, along with training in technical, economic, and policy aspects of energy, can make a significant difference.

1.4 Energy Assistance and Cooperation Programs

Numerous international and governmental agencies play a major role in providing loans and assistance to developing countries. The energy-related loans of the World Bank have grown to an annual level of $4 billion in recent years. Most of these loans are for power generation; there has been a growing emphasis on power sector loans for rehabilitation and improved transmissions and distribution. Loans from other international banks and from OECD nations, again primarily for power projects, total several billions of dollars annually. The United Nations and the Energy Sector Management Assistance Program (ESMAP) of the World Bank together provide less than $100 million per year for energy assistance in a variety of areas. The U.S. Agency for International Development provides somewhat more than $100 million per year for energy projects, training, small-scale demonstrations, and policy development. There is bilateral energy assistance from several other OECD nations.

The Department of Energy has been active in concluding international agreements for cooperative programs with a variety of countries concerning numerous energy technologies. These agreements permit joint undertakings, but little funding has been made available to carry them out. DOE has led an active multi-agency program, the Committee on Renewable Energy Commerce and Trade (CORECT), to promote technology transfer of renewable energy technologies. DOE has also initiated a program to spur the export of coal-based technology to developing countries. Each of these programs has annual funding somewhat greater than $1 million.

The DOE national laboratories have been active in a variety of programs to provide energy assistance to developing countries. More than $10 million annually are devoted to these efforts. Virtually all of the funding for these activities comes from outside DOE.

In spite of the variety of existing programs, most officials in developing countries concerned with energy matters argue that the overall level of energy assistance is inadequate. Many assistance agencies are reaching a similar view, especially given the recent concern about the relationship between energy decisions in developing countries and the global environment and the opportunities for energy technology exports from the developed countries.

It is useful to put the energy assistance to developing countries in perspective. We have identified annual loan activities, mostly for electric power, of about $6 billion per year. Including some bilateral and multilateral sources that we have not yet uncovered, the annual loan package may be on the order $10 billion. This is contrasted with an annual investment in the electricity

system alone of $50 to $60 billion per year, and an estimated need for twice that amount for power. (This is not including investment requirements of other energy supply sectors or for end-use efficiency improvements.)

We have identified technical assistance for energy on the order of $200 to $300 million per year from the AID, the United Nations organizations, and ESMAP. If one includes assistance from other countries and the technical support often derived from portions of the loan funds, the total is perhaps $500 million per year. This may be contrasted to the annual commercial energy costs of about $450 billion per year for developing countries. Thus, the assistance is on the order of 0.1% of total energy expenditures. It is not surprising that assistance from others has thus far made only limited contributions to solving energy problems in developing countries, considering the disparity between the magnitude of the problems and that of the assistance provided.

Stepping aside from the question of the overall level of support, there is broad agreement that the current programs of assistance are deficient in at least four respects: (1) in many cases they are not improving the performance of energy institutions in developing countries; (2) they are not directing enough attention to the benefits of energy efficiency improvements; (3) they are not getting improved energy technologies into use to meet developing country needs; and (4) they are frequently working from an inadequate technology and knowledge base due to the lack of RD&D to adapt energy technologies to developing countries.

1.5 Technology Transfer and the Need for Energy Technology RD&D

There are significant barriers to the effective transfer of technology to developing countries. Many of these are of an institutional nature: the policy environment is poorly developed, energy prices are held artificially low, hard currency for the purchase of technology is not available, and institutions are not in place to permit effective implementation of technology. Because of these difficulties, it is important that the problem of technology transfer be addressed in the context of assistance to improve the performance of institutions in developing countries responsible for energy.

Nonetheless, there have been important cases of successful transfer of technologies and capabilities to developing countries. Many of these have been in the area of energy efficiency, where the economic benefits have been apparent. Renewable energy technologies, especially in remote areas, have seen successes. Opportunities for fossil energy technologies are widespread, although the technology transfer efforts in this area, as in others, have been limited.

There is a substantial need for energy technology research, development, and demonstration to provide an underpinning to the technology transfer process. The needs are in four related areas:

(1) Adapting available technologies

Many seemingly attractive technologies are already available, but are not being used because the technologies need to be adapted to developing country conditions. Typically, for example, equipment needs to be able to operate with minimal maintenance and to withstand fluctuating voltages in power grids.

(2) Developing new or improved technologies to fill gaps in the portfolio of options

Although the energy technology portfolio has been considerably enhanced by the energy R&D investments of the 1970s and 80s, there remain a number of gaps which limit the choices available to a developing country. In the case of electric power generation, as discussed above, there is a great need for alternatives to fossil-based power and more efficient

fossil energy conversion.

(3) *Demonstrating innovative technologies*

Innovative technologies, whether adaptive or new, need to be demonstrated at a sufficient scale to establish operating parameters and costs so that the countries and lending institutions will consider the technologies to be commercially viable. Lending institutions tend to be conservative by nature and, in addition, do not fund the development and demonstration of innovative technologies.

(4) *Establishing and improving in-country energy R&D capabilities*

In-country energy R&D capabilities can help the country (1) evaluate and adapt imported technologies and (2) make effective use of other R&D being conducted in the country. There are often R&D projects that are best done using capabilities in developing countries. Finally, technology transfer and commercialization are often aided by the active involvement of in-country researchers.

A considerable number of useful RD&D activities along the lines indicated above could be developed and applied to the developing country context. As noted, such efforts need to be combined with active involvement in improving the energy institutions in developing countries. Participation of a variety of governmental agencies and of the private sector is needed to mount a successful program.

1.6 A Possible DOE Role

DOE has substantial qualifications to play an important role in providing energy assistance to developing nations. First and foremost, DOE is an energy technology agency. It has the expertise to mount a significant RD&D effort along the lines discussed above. DOE also has considerable expertise for training activities and other programs to improve energy decisionmaking in developing countries. Such efforts, if they are pursued, could best be done in concert with other U.S. agencies (especially AID, Commerce and State) and international bodies (the UN and the World Bank).

Considering the growing importance of developing nations to oil markets and the global environment, and as potential markets for U.S. technologies, the topic of energy technologies for developing countries is of growing importance. DOE has substantial capabilities to contribute to solutions of major global energy problems. It does not as yet have a clear mandate, mission, or sufficient programs to become a major player in working with developing countries.

In our judgment, the next step is for DOE, as part of its National Energy Strategy, to reassess its role in providing energy technology RD&D and technology transfer to developing countries. Additional efforts to develop more concrete plans will be necessary to establish major new programmatic activities related to energy technologies for developing countries, if the DOE is to play a significant role in this area.

1.7 Conclusions

We conclude that:

- a variety of enhanced energy technology R&D efforts is needed to adequately deal with a host of key developing country energy issues,
- creation of desirable energy choices and the adoption of improved energy technologies require broad and integrated programs, including substantial emphasis on technology transfer,

- opportunities exist for greater efforts to promote the use of technologies for more efficient end-use, non-fossil fuel supply, more energy-efficient and environmentally acceptable conversion of fossil fuel, and
- DOE has important capabilities to apply in concert with other public and private resources to meet these needs to encourage the adoption by developing nations of improved energy technologies.

2. Developing Countries and a U.S. National Energy Strategy

The emergence of the developing countries as a major and growing consumer of energy and energy services, both from indigenous and international sources, indicates that developing country energy issues should be considered in a reassessment of a U.S. national energy strategy. The key factors that influence a U.S. perspective on energy and developing countries are:

- *World energy availability and price, particularly for oil*

  Rising oil consumption by the developing countries will inevitably result in the world's oil demand more rapidly approaching its production capabilities, with normal market forces leading to higher prices sooner than otherwise. Periods of high oil demand have a higher potential of cartels (e.g., OPEC) again controlling the market and dramatically increasing prices. Also, rising domestic energy demand among developing country oil exporters may limit their export potential. Thus, U.S. prospects for importing oil at reasonably predictable prices are linked to the oil use of the developing world.

- *Global environmental concerns associated with increasing energy use*

  The growing use of fossil fuels by developing countries will increase the release of carbon dioxide (CO_2) and possibly other greenhouse gases (e.g., methane), with a corresponding increase in the potential for global climate change. Of particular concern in this regard are China's plans to massively increase its use of coal. In addition, there are concerns related to certain energy-using devices, chiefly domestic refrigerators and air conditioners, since essentially all those presently available use chlorofluorocarbons (CFCs). Many developing countries have experienced dramatic growth in the use of these products; others are likely to see growth in the future.

- *Potential markets for U.S. energy and energy technologies*

  Growth in energy demand and the services provided by energy provide opportunities for the U.S. to export raw materials, products, and technology. As discussed in later sections, the situation presents a substantial challenge since "off the shelf" products that are suitable for the U.S. (and other industrialized countries) are often not suitable for developing countries. On the other hand, in some cases the international market can support energy technologies that are not presently cost competitive in the U.S. Thus, the international market may provide support for a U.S. industry while it develops a product that is eventually cost-effective in the U.S. domestic market as well. For example, developing countries have many people and commercial activities far from the electrical grid and from fuel supplies; as a result, photovoltaic systems and other renewable energy technologies have seen considerable applications in developing countries.

It could well be in the U.S. interest to play a leadership role in helping the developing countries make critical energy decisions. Better technologies for providing energy sources and for converting and using energy more efficiently can be powerful tools for achieving both U.S. and developing nation objectives.

The issue of global warming is worthy of particular consideration. The development and export of cost-effective energy technologies that reduce growth or increase efficiency of the use of fossil fuels could mutually benefit the U.S. and developing nations. These objectives could be achieved through increasing efficiency of converting fossil fuel to electricity, increasing efficiency of end-use devices, reducing transmission, distribution, and transport losses, and

developing non-fossil alternatives to fossil energy supply. New, active programs in these areas could contribute to a leadership role for the U.S. on global climate change issues. Many such programs might best be accomplished through cooperative multilateral efforts with other industrialized nations. At the same time, such programs might serve to reduce political tensions among developed and developing nations on global environmental concerns. Thus, by providing targeted energy technology assistance to developing nations, the U.S. and other industrialized nations could (1) achieve multiple domestic and international objectives, (2) demonstrate constructive actions to deal with potential global warming, and (3) increase cooperation among industrialized nations and reduce tensions between the developed and developing regions of the world.

3. The Energy Situation in Developing Countries

3.1 Overview

3.1.1 The increasing importance of the developing countries to the world energy picture

Over the past two decades, the share of world energy consumption accounted for by developing countries has increased. In 1970, the developing country share of world primary commercial energy consumption was 16%; by 1987, this share had grown to 25% (Figure 1).[1] This change resulted from the combination of fast growth in developing country energy consumption (5.2% per year between 1970 and 1987) and much slower growth in the OECD countries (1.0% per year). The developing country share of world oil consumption has grown in similar fashion: from 14% in 1970 to 24% in 1987.

The relatively rapid growth in commercial energy consumption in the developing countries has been the result of population growth, urbanization and the accompanying modernization of people's way of life (for example, greater ownership of automobiles and electric appliances), and growth in industrial production. In the oil-exporting developing countries, increases in oil revenues have played an important role in accelerating industrial and personal energy consumption.

3.1.2 Differences in energy consumption among the developing countries

Growth in energy demand has been much faster in some parts of the developing world than in others (Table 1). In the 1970s, increase in energy consumption was particularly rapid in South East Asia and China. Between 1979 and 1987, growth ranged from only 2.9% per year in Latin America to 6.5% in South Asia.

Table 1

Historic Growth in Primary Commercial Energy Consumption in the Developing Countries

(% per year)

	1969-79	1979-87
Latin America	5.8	2.9
South East Asia	9.0	4.9
South Asia	3.8	6.5
China	7.7	3.4
Middle East	6.3	5.4
Africa	5.8	3.7
Total	6.5	3.9

Sources: British Petroleum, 1988; Lawrence Berkeley Laboratory. The regional shares of total energy consumption in 1987 were: Latin America (21%), South East Asia (11%), South Asia (12%), China (37%), Middle East (9%), Africa (11%).

[1] Developing countries here include all countries in Africa, the Middle East, Asia (except Japan), and Latin America and the Caribbean. This definition includes the newly industrialized countries of Asia. The term *energy consumption* as used in this report refers to modern forms of energy; it does not include biomass fuels, for which consumption statistics are not well documented. For a report summarizing current knowledge of the use of biomass for energy, see "Biomass Fuels in the Developing Countries: An Overview," S. Meyers and G. Leach, LBL-27222, July 1989.

Growth in commercial energy consumption by the developing countries was slower in the 1980-1987 period (3.9% per year) than in the 1970s (6.5% per year). This was mostly due to economic stagnation in Latin America and Africa, and slower growth in China, which alone accounts for 37% of total commercial energy consumption by developing countries. The increase in 1987 (5.2%) was higher than the average for the 1980-1987 period, mostly due to faster growth in Asia.

3.1.3 Energy production in developing countries

In many developing countries, the increase in energy consumption has been supported by growth in domestic energy production. This growth has included oil, natural gas, hydroelectricity, and coal, with the importance of each of these varying according to the situation of individual countries. Exploitation of these resources was accelerated by the increase in oil prices in 1973-74 and 1979-80. In the case of oil, much of the increased production has been exported, but domestic consumption is claiming an ever greater share of production.

An important issue for a number of developing countries is development of natural gas resources. Economically-attractive resources exist in many countries, but they tend to be difficult to develop because the main market for the gas is local and foreign oil and gas companies are thus unable to recoup their investment through hard currency earnings. Assistance in development of gas resources and the infrastructure required for gas transport is beginning to receive more attention. Nonetheless, few developing countries have as yet indicated major plans to develop or use natural gas resources.

3.1.4 Future energy consumption in developing countries

The future rate of increase in energy consumption in the developing countries will depend on many factors, including the world economic situation, the price of oil, the outcome of debt negotiations, economic and trade policies, and availability of capital for the energy sector. Regional differences may become more marked: for example, growth in energy consumption seems certain to be faster in South and East Asia than in Latin America and Sub-Saharan Africa.

A recent end-use based scenario of world primary energy consumption by region show the share of total energy use in the developing countries (including China) growing from 23% in 1985 to 29% in the year 2000 and to 44% in 2025 (Table 2 and Figure 2).[2] Of course, the relative importance of the developing countries will depend both on their growth and the evolution of energy consumption in the OECD and in the USSR and Eastern Europe. But the high rate of population growth in developing countries and the nature of the development process, along with the structural change in the OECD toward less energy-intensive economic growth, ensure that the share of world energy consumption accounted for by developing countries will continue to increase in the coming decades.

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[2] The scenario shown was adapted by Lawrence Berkeley Laboratory (LBL) from scenarios prepared by LBL and the World Resources Institute for the U.S. Environmental Protection Agency's Report to Congress on global climate change, *Policy Options for Stabilizing Global Climate*. The numbers shown in Table 2 are the midpoint between the low and high growth scenarios prepared for EPA. The assumed average annual gross domestic produce (GDP) growth rates for this "medium" scenario for 1985-2000 and 2000-2025 are as follows: U.S. (2.5%/2.0%), other OECD (2.7%/2.0%), USSR/E. Europe (3.6%/3.1%), China (4.5%/4.0%), other LDCs (3.9%/3.5%).

Table 2

Scenario of Future Primary Energy Consumption in the World
(Quads)

	1985	2000	2025
US	71	80	90
Western OECD	64	71	76
Eastern OECD	18	22	23
USSR & E. Europe	67	88	105
China	23	37	81
Middle East	6	9	21
Africa	7	12	28
Latin America	15	23	50
South & East Asia	14	24	52
World Total	**285**	**366**	**526**

Source: Lawrence Berkeley Laboratory, based on scenarios prepared by LBL and the World Resources Institute for the U.S. Environmental Protection Agency, Sept. 1989.

3.1.5 Lack of capital for the energy sector of developing countries

A shortage of capital for investment in the energy sector often constrains resource development, which in turn inhibits energy and economic growth in many countries. The problem is particularly acute in the power sector, where new energy facilities tend to be highly capital-intensive. Many developing countries already face power shortages that cause considerable loss of economic production and demand for electricity is growing rapidly in most of these countries. The U.S. Agency for International Development (AID) estimated in 1988 that if the performance of power systems in the developing world remains the same as today, and economic growth averages 4.5% per year, the developing nations as a group would require 1,500 GW of additional generating capacity between 1988 and 2008.[3] (Current total installed capacity in developing countries is about 500 GW.) This expansion would cost over $2,600 billion, or an average of over $125 billion per year. Currently, around $50-60 billion is being spent per year.

Many developing countries already invest a substantial portion (commonly between 20 and 40%) of public funds in energy. This allocation of investment to energy, in itself insufficient to keep up with rising energy demands, also reduces investment in other sectors, thus further straining many economies and limiting strategic economic growth objectives.

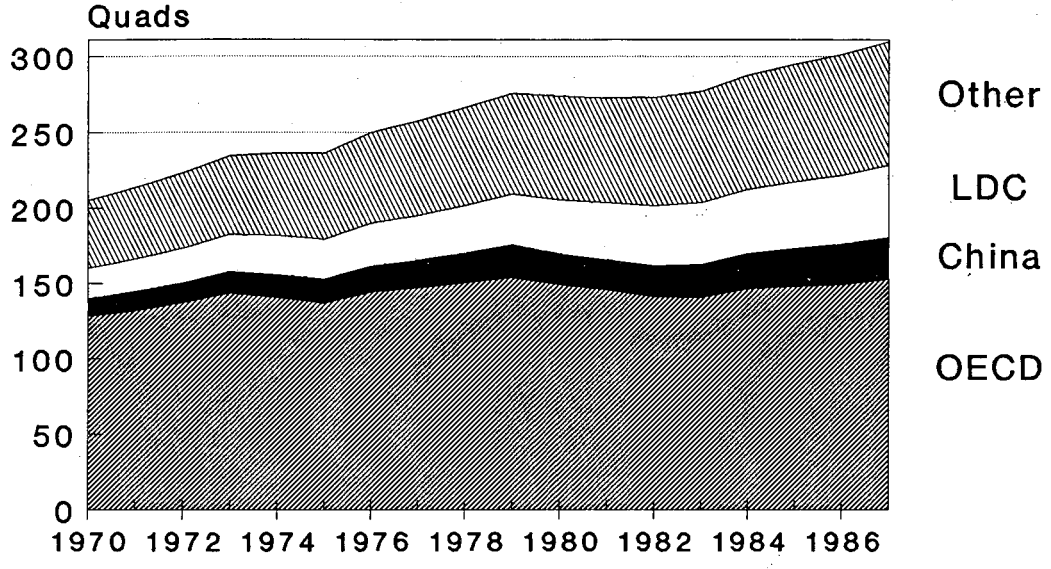
3.1.6 Inefficiency in energy supply and end-use in developing countries

One way to reduce the amount of investment required for power system expansion and for development of other resources, or to reduce expenditures on energy imports, is to improve the efficiency of energy production and end-use. The inefficiency with which energy is used and, in

[3] U.S. Agency for International Development, *Power Shortages in Developing Countries: Magnitude, Impacts, Solutions, and the Role of the Private Sector,* March 1988.

Figure 1

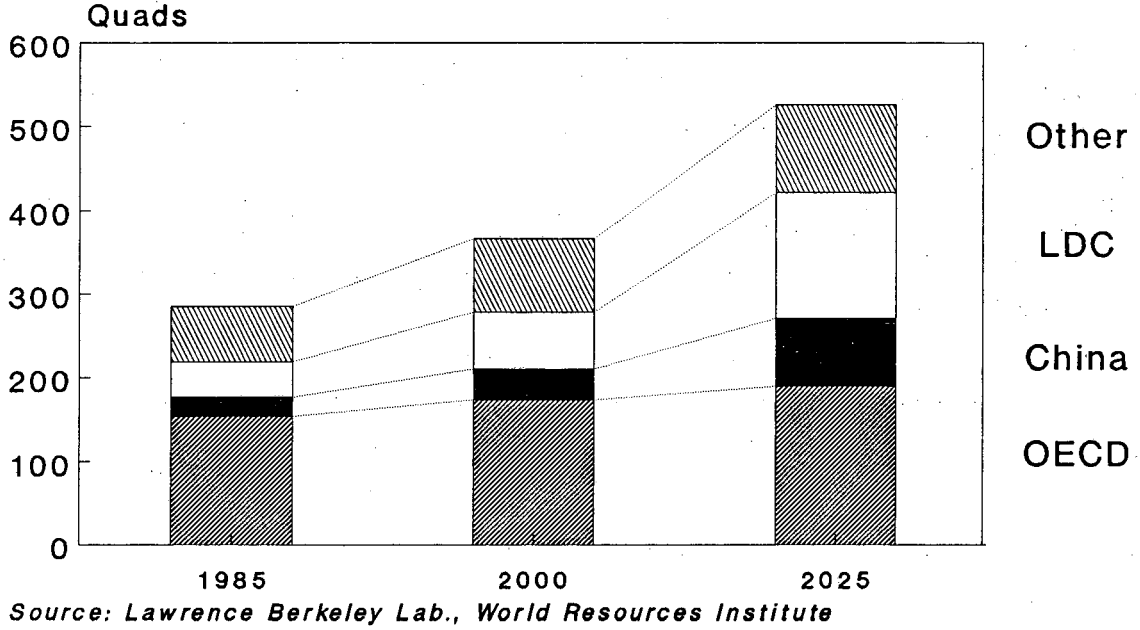
WORLD PRIMARY ENERGY CONSUMPTION 1970-1987



Source: BP Statistical Review of World Energy, 1988

Figure 2

PROJECTED PRIMARY ENERGY CONSUMPTION 1985-2025



Source: Lawrence Berkeley Lab., World Resources Institute

LDC=Africa, Middle East, Asia(except Japan & N.Korea) & Latin America
Other=USSR, E.Europe, N.Korea, & Cuba.

the case of electricity, produced and distributed, has accelerated growth in energy consumption in many developing countries. This inefficiency is the result of many factors: the prevalence of old equipment (often used equipment purchased cheaply from wealthier countries) and processes, lack of maintenance, poor management, lack of information or expertise, and in many cases, energy pricing policies that provide little incentive for more efficient energy use. Some of these problems are due to lack of capital for investment in new equipment and shortage of skilled human resources.

An example of inefficiency in the power sector is the magnitude of electrical transmission and distribution (T&D) losses in many developing countries. These are often over 15% of generation and are over 20% in some cases (Table 3). This compares to T&D losses in the range of 7 to 9% for most OECD countries. The reasons for high losses include extensive use of low voltage distribution networks and theft of electricity.

Table 3

Electrical Transmission & Distribution Losses
(Percent of generation, 1981-85 average)

Pakistan	28
India	22
Thailand	18
Philippines	18
South Korea	12
Japan	7
U.S.	8

Source: U.S. Agency for International Development

Energy is often used inefficiently in industry, transportation, and buildings of developing countries relative to the norm in the industrialized countries. In China, for example, the average energy consumption per unit of output for various industrial products is much higher than that in the U.S. or Japan (Table 4). Another example of a high level of inefficient energy use is industry in Egypt. The typical fuel use per unit of product is 75% higher in glass and in chemicals, 90% higher in cement, and 100% higher in petroleum refining than typical levels found in industrialized countries.[4] Electricity intensity is also much higher than international standards for such manufacturing sectors as glass, ammonia, and metal production as well as food processing. A major cause of this high energy intensity has been historically very low energy prices.

The overall impact of improving the efficiency of energy production and use could be substantial. In the power sector, the AID study estimated that improvements in electricity generating efficiency, sharp reductions in transmission and distribution losses, and increases in electricity end-use efficiency could reduce the need for additional generation capacity from 1,500 GW to approximately 1,200 GW, thereby saving over $500 billion over the next 20 years.

[4] "Energy Conservation and Efficiency Program Design Report (Egypt)," RCG Hagler, Bailly, Inc., April 2 1987.

Table 4

Final Energy Consumption per Unit Product, mid-1980s
(GJ per ton)

	Steel	Synthetic ammonia	Cement clinker	Oil	Paper
China	33	59	5.9	2.8	48
U.S.	-	34	-	-	35
Japan	23	-	3.5	2.1	-

Source: Tsinghua University, Beijing, China

3.2 Developing Country Problems and Perspectives

Developing countries exhibit tremendous diversity among energy, economic, and environmental problems as well as resources to deal with these problems. While the developing nations share the problems of low average income and inadequate industrial plant, technological capabilities, and infrastructure, their particular situations (from both their own and the U.S. perspectives) are highly varied. Any attempt to deal with them from a monolithic perspective will lead to oversimplification and misinterpretation. To better understand their energy problems, it is useful to place them in several groups that face similar issues with respect to energy.

3.2.1 Oil Exporters with Large Reserves Per Capita

These are the oil-rich countries of the Middle East. While many of these nations are typically no longer classified as developing countries (e.g., by the World Bank), they share many problems with them and continue to be of importance to the U.S. because of their vital role as oil suppliers and their importance to U.S. security interests.

Much of their attention is devoted to oil supply issues, including oil prices, market share, instability in international oil markets, and downstream investments in oil. With the decline in oil prices, these countries (e.g., Saudi Arabia) are presently struggling to maintain efforts to diversify their manufacturing and industrial base. Rapid growth in electricity demand, particularly for air conditioning, has led to shortages of peak power. Subsidized prices for electricity contribute to inefficient use. Development of natural gas resources, combined with their use in efficient gas turbine technology, has the potential for providing new sources of power.

3.2.2 Oil Exporters with Small Reserves Per Capita

These countries are geographically diverse. Examples in Latin America are Mexico and Venezuela; in Africa, Egypt and Nigeria; and in Asia, Indonesia. The major issue is concern over declining availability of oil for export and, thus, reduced oil revenue in the future. Solutions lie in finding substitutes for domestic oil use, using energy more efficiently, and diversifying the economy while oil revenues last. There is a particular need for assistance in natural gas exploration and development in many of these countries as the natural gas resource base is generally large. Flaring of natural gas, because of inability to productively use associated gas, is unavoidable unless investments are made to bring gas to domestic markets. Because profits are in local currency, it is difficult to attract foreign investment for this purpose.

Most of these countries are presently saddled with enormous debt problems, making their long-term economic prospects much less promising despite oil revenues. Many have electricity

shortages. Most have heavily subsidized fuel prices and face strong political difficulties in removing the subsidies. This has led to very inefficient uses of energy. These countries are now much more open than in the past to assistance in alternative supply technologies and methods to increase efficiency of energy use to have more oil to earn foreign exchange in the short term and to conserve oil resources for the longer term.

3.2.3 Large Developing Countries with Energy Resources

China, India, Brazil, and Indonesia are especially important because of the magnitude of their current or potential energy consumption and their impact on global climate change. China and India are critical because their already substantial use of coal is projected to increase at a high rate. Brazil is noteworthy because of deforestation in the Amazon. Indonesia is currently consuming its large forests and is implementing plans to increase its use and export of coal.

These large countries face the whole complex of energy problems. Key issues include: exploration for oil and natural gas, the development of these and other fuels, improved utilization of biomass resources, improving energy efficiency, and applying a wide range of new energy technologies (for supply and demand applications). Concern about inadequate capacity for generating electricity dominates the capital for energy development issues in these countries. They have experienced rapid increases in residential and commercial electricity demand, which are outstripping (still high) industrial demand growth. Urbanization in these countries is providing greater impetus to electricity demand growth, while subsidized electricity prices (in China, India, and Indonesia) intensify demand growth and contribute to existing electricity shortages.

3.2.4 Low-income Nations with Slow Development

This category includes much of Africa. The energy-related problems of the low-income countries are very serious. Most of these countries have seen continued energy and oil demand growth, even in times of economic contraction and higher energy prices. They have seen their currency devalued against the U.S. dollar during the past decade, which has meant that the cost of imported oil is higher than previously because oil is valued in terms of hard currencies. Energy imports often represent a substantial portion of total export earnings and capital for energy infrastructure is a sizeable portion of total capital investment.

3.2.5 Rapidly Developing Countries

The more rapidly developing countries (e.g., Thailand and Malaysia) and the newly industrializing countries (South Korea, Taiwan, and Singapore) represent substantial opportunities for expanded energy-related trade and joint ventures. Energy-related trade with the newly industrialized countries is already significant with respect to coal, renewable energy technology, and equipment associated with energy supply and use.

3.2.6 Eastern Europe

Some of the centrally-planned economies of Eastern Europe face energy problems similar to those of the more industrialized developing countries and are in fact recipients of development assistance from the World Bank and the UN. As these countries increasingly open their economies to the international market, there will be more opportunities for energy-related trade. Environmental issues and energy efficiency have recently become important topics in Eastern Europe, as a part of the political reforms overtaking the region. Assistance to Eastern Europe from OECD nations to deal with economic, energy, and environmental problems is a new and important topic on the international agenda.

3.3 Summary

Energy growth in the developing countries has been very rapid during the past fifteen years, particularly when contrasted with industrialized countries. The exact mix of problems faced by the different developing nations varies considerably. It is clear, however, that they have very substantial unmet needs. Capital is inadequate and predicted to become an increasingly serious problem, particularly for electric power. The application of the latest energy technology and the R&D effort to make the technology sustainable could help ameliorate this problem. Limited capital and resources must be put to the most efficient uses; technology and knowledge are essential for this task – and they, too, are relatively inaccessible to developing countries.

4. Current Energy Assistance and Cooperation Programs with Developing Countries

Energy assistance for developing countries consists of a variety of activities conducted by a great many parties. The assistance is dominated by lending for power plant construction, but includes technical assistance in many other energy-related areas. The total level of assistance is difficult to estimate. No single source covers all the different types of assistance, and the various organizations do not necessarily have good communications among themselves. It is not uncommon in a developing country for two or more organizations to be undertaking related activities in an uncoordinated manner, although recent years have seen greater efforts at coordination of activities by organizations working in a particular area (e.g. innovative approaches in the power sector, improved cookstoves, and energy research).

4.1 What is being done and by whom?

There are several types of energy-related assistance that are being provided to the developing countries. These include: (1) loans (with repayment terms that vary greatly); (2) grants for energy equipment; (3) technical assistance; (4) training and institution building; and (5) sponsorship of research. The degree of emphasis differs among the various multilateral and bilateral institutions involved in providing assistance. The level of assistance in a recent year is shown in Table 5 for the major institutions.

4.1.1 International institutions

The major players in energy assistance in terms of funds distributed are the multilateral lending organizations that draw on the combined financial resources of the industrialized countries. These are the World Bank (which includes the International Bank for Reconstruction and Development [IBRD], the International Development Association [IDA], and the International Finance Corporation [IFC]), and the regional development banks: the Asian Development Bank (ADB), the Inter-American Development Bank (IADB), and the African Development Bank. These institutions are the lenders of capital for energy facilities and projects for which private-sector capital markets are not adequate to meet the need, and the terms are more favorable than those offered by commercial loans. IBRD loans, which account for the bulk of World Bank loans, generally have a grace period of three to five years; the interest rate is related to the Bank's cost of borrowing. The regional banks operate in a similar fashion. The IDA serves the poorer developing countries, providing interest-free credits with ten-year grace periods and forty-to-fifty-year maturities. The IFC raises financing for private companies and joint ventures, or may take an equity position in a project. Its interest rates are more in line with commercial lending.

The *World Bank's* annual energy lending (including credits from the IDA) has quadrupled from $1 billion in fiscal 1977 to about $4 billion in fiscal 1987.[5] (About one-fifth of total Bank lending is directed for energy.) Besides its traditional lending for specific energy projects, the Bank is diversifying its lending instruments by providing increasing amounts for structural and sector adjustment loans and sector investment loans. Through this means, the Bank has increased its energy policy and advisory role, and is placing greater emphasis on policy and institutional reforms and economic efficiency (especially reform of energy pricing).

[5] The World Bank Industry and Energy Department, *Recent World Bank Activities in Energy*, June 1988.

More than two-thirds of the Bank's energy lending is directed to electric power. Transmission and distribution, including rural electrification, now absorb about one-half of the Bank's power lending. The remainder of power sector funds cover generation projects of many types, including rehabilitation. The Bank also funds coal mining projects and a range of oil and gas operations. The Bank is emphasizing assistance for energy supplies for the domestic market, especially for natural gas development.

Table 5

Funding Levels for Major Energy Assistance to Developing Countries

Organization	Activity	$ Million	Year
Loans			
World Bank	power sector loans	3025	FY1987
	oil and gas loans	679	FY1987
ADB	energy project loans	567	1988
IADB	energy sector loans	405	FY 1988
Japan	power and gas loans	1100	FY 1988
W. Germany	energy loans	410	1988
Grants and Other Assistance[*]			
US (AID)	energy projects	130[†]	FY 1988
UN (DTCD)	technical assistance	25-30	1988
UN (FAO)	rural energy assistance	20-30	1988
UN (UNIDO)	industrial energy assistance	5-10	1988
ESMAP	preinvestment studies & training	14	1988

[*] The main organizations not listed are the UN regional commissions and the development agencies of the OECD countries other than the U.S.
[†] To increase to $237 million (est.) in FY 1989.

The *regional development banks* fund a similar range of energy sector activities as the World Bank, though at a lower level. The ADB allocated $567 million in funds for energy projects to developing countries in Asia and the Pacific in 1988, a sharp increase from the $332 million provided in 1987. Similar to the World Bank, the ADB encourages policy reforms among its developing country members. The IADB provided a total of $405 million in loans for energy projects in Latin America and the Caribbean in FY 1988.

Funding by the Banks is dominated by loans for power systems of proven technology where revenue streams are reasonably well-assured. Relatively little money has gone to small energy facilities, to rural energy needs, or to pilot plants of new technologies.

Other multilateral organizations operate more by providing technical assistance and other services rather than large amounts of capital. At least 10 to 15 organizations of the United Nations (UN) are involved in various types of energy assistance. The organizations with the most substantial level of activities in the energy field are the Department of Technical Cooperation for

Development (DTCD), based in New York, the Food and Agriculture Organization (FAO), based in Rome, the Industrial Development Organization (UNIDO), based in Vienna, and the five regional commissions. These organizations have various sources of funding (including crossflow of funds among them), but many of their projects are supported by the *UN Development Programme* (UNDP). As of the end of 1988, UNDP was supporting some 165 energy projects; UNDP's contribution to these projects over their lifetime (averaging about five years) is about $140 million.

The *Department of Technical Cooperation for Development* provides assistance in the exploration, development, and use of most forms of non-nuclear energy. The main areas of DTCD's energy activities are (1) energy advisory services, assessments, and surveys; (2) energy project formulation, implementation, and assistance; and (3) sponsorship of meetings, symposia, and workshops. Its work has led to establishment of energy planning and information systems, discoveries of hydrocarbon resources, organization of petroleum exploration and development institutions, development of geothermal and small-scale hydro power plants, establishment of solar, wind, and biomass demonstration projects, and training programs for scientists, technicians, and managers. DTCD is currently involved in 110 projects in 47 countries; 75 to 80% of these projects are funded by UNDP.

The *Food and Agriculture Organization* is active in energy assessment and planning for rural and agricultural development, fuelwood and charcoal, biogas and gasification, solar and wind energy, and animal power. FAO's approach emphasizes the development of consolidated national programs which include training, institutional, and financial aspects as well as construction and diffusion of physical systems. The *Industrial Development Organization* provides assistance related to improving use of energy by industries in developing countries. The five *regional commissions* support a variety of energy-related projects, some of which involve many countries within a region.

An example of cooperation among organizations in providing energy assistance is the *Energy Sector Management Assistance Program* (ESMAP), which was instituted jointly by the World Bank and the UNDP in 1983 to conduct energy sector assessments, facilitate implementation of energy policy recommendations, and to help stimulate investment. ESMAP carries out energy-related preinvestment and prefeasibility studies in more than 50 countries and provides a wide range of institutional and policy advice to developing countries. The program's activities are organized into two major groupings, one of which addresses institutional, financial, and policy issues in the energy sector, and the other of which focuses on issues affecting energy use and provision in households and rural industries. Support for ESMAP activities comes from a number of country donors (Canada and Europe) as well as the UNDP and the Bank. Over $500 million in projects originally identified under ESMAP activities have been financed by either private enterprise or multilateral and bilateral donors.

The *European Economic Community* (EEC) also provides energy assistance to developing countries. This includes grants for purchase of equipment manufactured in EEC countries and technical assistance in various areas.

The *International Energy Agency* sponsors the Energy Technology Data Exchange (ETDE) and the Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDETT). Both of these programs facilitate technology transfer by disseminating information about energy technologies. The *International Atomic Energy Agency* exchanges information dealing with nuclear science, technology, and civilian power through the International Nuclear Information System (INIS). These programs, while not directed at developing countries, are open

to their membership.

4.1.2 Bilateral assistance

In addition to the multilateral programs described above, most of the industrialized countries are directly involved in energy assistance to developing countries. These are usually carried out by a single development assistance agency, but other agencies may also be involved in activities such as trade promotion. With some exceptions, most of these bilateral programs are at a lower dollar level than for the multilateral organizations. Except for the program run by Japan and West Germany, they tend to be more oriented toward direct assistance as contrasted with lending.

Particular programs range from resource/technology assistance, technology transfer assistance, training, assistance for energy planning, and concessionary arrangements for energy commodity purchases. The target of energy assistance by bilateral agencies is more likely to be the rural sector than is the case with the loans from the Banks. Often, assistance is tied to purchase of equipment manufactured in the donor country (AID is a notable exception to this rule). In many cases, a country's programs pay special attention to certain countries or regions (e.g., the U.S. to Egypt and Pakistan, France to French-speaking Africa, Japan to Indonesia). Japan has made a recent commitment to increase its development assistance, but it is not yet known what this commitment will mean for energy sector programs. (U.S. activities are described below.)

4.1.3 Other assistance

A number of nongovernmental organizations (NGOs) offer energy assistance to developing countries. This includes foundations and other philanthropies, voluntary groups, and research centers. The activities of these groups are widely varied — from analysis to grants, training, and field technical assistance — and difficult to document in terms of overall emphasis and funding levels. In many cases, however, relatively inexpensive programs of this type have had substantial impacts in particular localities.

4.1.4 Energy research relevant to developing countries

Various international and national organizations sponsor research that is targeted to developing country energy needs. This includes research on policy issues, development of analytical tools, promising energy technologies, and improvement of project implementation. Some of this research is conducted in the developing countries, usually collaboratively with researchers from the sponsoring country. There is also support for research conducted by developing country scientists, such as that sponsored by the International Development Research Centre in Canada. In addition to research that is directly targeted to developing country energy needs, there is also much energy research sponsored by governments in industrialized countries that is potentially applicable in developing countries, though it is not conducted expressly for that purpose.

4.1.5 U.S. assistance

Turning specifically to the U.S., there are a number of government agencies that provide various types of energy assistance to developing countries. The *Agency for International Development* (AID) provides energy assistance in the form of policy advice, training and institution building, technical assistance, research, and technology transfer. Capital assistance is provided to only a few countries. While AID is involved in several dozen countries, the bulk of energy-related assistance goes to a few countries (especially Egypt and Pakistan). The objectives of AID's current energy activities focus on three primary areas: energy efficiency, the expansion of energy supplies, and the use of cleaner technologies, including both conventional fossil fuels

and renewable energy sources. Projects are not centrally managed, but developed by AID missions in individual countries.

AID's assistance is increasingly used to encourage the expansion of private sector energy activities. AID has concentrated considerable effort on reform in the power sector (particularly supporting the development of private power and cogeneration facilities) and is increasing its efforts to provide technical assistance on energy efficiency. AID has also emphasized technology transfer, especially to meet needs for electricity services, by such initiatives as the Program to Accelerate the Commercialization of Energy Research (PACER) in India. Total energy assistance by AID is increasing considerably from FY 1988 ($130 million) to FY 1989 ($237 million), mainly due to power sector assistance in Egypt.

A central Office of Energy (with an annual budget of $10 million) develops new approaches to energy problems and applies these worldwide in collaboration with missions. The areas of its current activities include investment planning in the power sector, energy price reform, energy conservation and demand management, renewable energy applications and training, biomass-fired power systems, household fuels, and resource assessment and development of indigenous fuels. The Office of Energy coordinates the Multiagency Working Group on Power Sector Innovation (MAGPI), an effort designed to improve communication among programs dealing with this area, including activities within the World Bank, the UN, and AID itself.

The U.S. *Trade and Development Program* (TDP) in the U.S. International Development Cooperation Agency finances a variety of planning services for projects in developing countries that are potential export markets for U.S. goods and services. TDP focuses on large public sector projects, including energy development. Its loans in the energy sector amounted to $6 million in FY 1988.

The *Department of Energy* (DOE) is involved in a variety of ways with energy assistance to developing countries. As part of its international energy R&D cooperative activities, DOE currently has over thirty bilateral agreements with developing countries, principally in the newly industrialized countries (Appendix A). Cooperation in fossil energy, nuclear power, renewable energy and conservation has been pursued with several countries, including Mexico, Venezuela, Brazil, South Korea and Taiwan. With Mexico, for example, DOE is currently engaged in cooperative activity in fossil and geothermal energy, while in Venezuela, there is ongoing cooperation in enhanced oil recovery and conservation. For the most part, cooperative energy R&D activities in the developing countries have been limited to exchanges of information and research personnel.

DOE also chairs and staffs CORECT (Committee on Renewable Energy Commerce and Trade), an interagency committee with the mission: "to promote the commerce of renewable energy products and services."[6] CORECT is intended to stimulate markets for U.S. solar and other renewable energy technologies by establishing links between U.S. firms and potential buyers in the developing world (Appendix B). A recent CORECT initiative, the Integrated Electric Utility Program (IEUP), seeks to promote decentralized electric power systems using renewable energy sources for electric utilities in developing countries.

Recently, DOE initiated a program to spur the export of coal-based technology to developing countries. This program, run by the Assistant Secretary for Fossil Energy, is funded at a level of $1.1 million per year (Appendix C). Of this amount, $750 thousand is used to co-fund (with

[6] The other agencies include AID and the Departments of Commerce and State.

AID or TDP) prefeasibility studies by U.S. companies to promote international energy trade opportunities. The remainder of the funds are used to support a variety of studies (especially market assessments), conferences, meetings, a directory of U.S. coal and coal technology resources, and similar efforts. The Assistant Secretary (Fossil Energy) chairs the DOE Coal Export Initiative Program, which involves coordination with the major U.S. agencies concerned with trade issues. Recently, DOE concluded an arrangement with Costa Rica for the deployment for clean coal technologies. This arrangement is likely to be the forerunner for others aimed at promoting U.S. energy trade, as efforts continue with other countries in the identification of energy market opportunities.

The DOE *National Laboratories* have emphasized working with individual countries, or regional grouping of countries (Appendix D). Supported by AID and DOE, Oak Ridge National Laboratory (ORNL), has assisted more than 20 developing countries with energy planning, technology assessment, and investment analysis. Its work has given attention to renewable energy options (especially biomass and hydropower), fossil energy options, and efficiency improvement, as well as to such cross-cutting issues as institution-building, energy policy reform, and environmental management.

Lawrence Berkeley Laboratory (LBL), with support from AID, is working with Southeast Asian countries to develop technical capabilities and policies in those countries for the more efficient use of energy in commercial buildings. Recently LBL has started to work with China on energy policy issues related to global climate change. LBL also has an extensive ongoing energy data gathering and analysis effort in collaboration with more than 20 developing countries, supported by international oil companies and the U.S. Environmental Protection Agency.

Argonne National Laboratory (ANL) has been active in energy system planning for the World Bank and others — including model development, country studies, and training — for a number of countries. Current ANL work in this area involves Indonesia, Malaysia, Egypt, Poland, Hungary, and Sri Lanka. ANL has provided technical assistance and training to developing countries in electric system expansion planning and analysis of electricity tariffs. ANL, with DOE support, has been active in coal technology assessments aimed at specific markets in developing countries.

Los Alamos National Laboratory (LANL) has been involved for several years in a substantial program to provide technical assistance to the nations of the Caribbean in the areas of geothermal energy (Honduras, El Salvador, Costa Rica, St. Lucia, and Guatemala), peat development (Costa Rica and Panama), and energy and economic planning (all of the above).

In addition to supporting CORECT's technology assistance efforts, Sandia National Laboratory (SNL) has been involved in transfer of photovoltaic system technology worldwide through its Design Assistance Center. The Solar Energy Research Institute (SERI) provides support for international renewable energy activities through the Wind Energy Technical Assistance Center.

4.2 How well is it working?

Most officials in developing countries concerned with energy matters argue that the overall level of energy assistance is inadequate. Many assistance agencies are reaching a similar view, especially given the recent concern about the relationship between energy decisions in developing countries and the global environment and the opportunities for energy technology exports from the developed countries.

Stepping aside from the question of the overall level of support, there is broad agreement that the current programs of assistance are deficient in at least four respects: (1) in many cases they are not improving the performance of energy institutions in developing countries; (2) they are not directing enough attention to the benefits of energy efficiency improvements; (3) they are not getting improved energy technologies into use to meet developing country needs; (4) they are frequently working from an inadequate technology and knowledge base due to the lack of R&D to adapt energy technologies to developing countries.

The World Bank recently undertook a critical review of its lending program for electric power systems.[7] The results show that over the past decade power sector performance has been in decline, or has been stagnating at unsatisfactory performance levels. A number of factors, largely institutional, are identified as contributing to this situation, including: a trend towards large government-controlled utilities with undue interference by the government in utility operations, ineffective planning, inadequate maintenance, and prices that for social reasons do not reflect the cost of electricity production. The report also notes the lack of balance between loans for new power plants (too high) versus funds to increase transmission and distribution performance and to improve performance of existing facilities. A series of recommendations are made for improving performance, and in particular the efficiency with which electricity is generated and utilized.

4.3 Conclusions

There are many agencies that are assisting developing countries with their energy problems. Traditionally, this assistance has been directed at energy supply technologies, with particular emphasis on the power sector. These emphases are changing: within the power sector, more attention is being given to reducing transmission and distribution losses and to increasing rural electrification. In the past several years, increasing attention has been paid to energy efficiency programs. Many of the lending agencies are promoting energy policy reforms, especially pricing.

Some observers believe that these changes are taking place much too slowly. Others disagree. Virtually everyone, however, agrees that the energy problems of developing countries are becoming less tractable for them and more significant for industrialized countries as well.

It is useful to put the energy assistance to developing countries in perspective. We have identified annual loan activities, mostly for electric power, of about $6 billion per year. Including some bilateral and multilateral sources that we have not yet uncovered, the annual loan package may be on the order $10 billion. This is contrasted with an annual investment in the electricity system alone of $50 to $60 billion per year, and an estimated need for twice that amount for power. (This is not including investment requirements of other energy supply sectors or for end-use efficiency improvements.)

We have identified technical assistance for energy on the order of $200 to $300 million per year from the AID, the United Nations organizations, and ESMAP. If one includes assistance from other countries and the technical support often derived from portions of the loan funds, the total is perhaps $500 million per year. This may be contrasted to the annual commercial energy costs of about $450 billion per year for developing countries. Thus, the assistance is on the order of 0.1% of total energy expenditures. It is not surprising that assistance from others has thus far made only limited contributions to solving energy problems in developing countries, considering

[7] "A Review of World Bank Lending for Electric Power," The World Bank, March 1988.

the disparity between the magnitude of the problems and that of the assistance provided.

5. Technology Transfer and the Need for Energy Technology RD&D

5.1 Overview

The energy technology choices being made by developing countries are important to the United States from the perspectives of (1) world energy availability and price, particularly for oil, (2) potential markets for U.S. energy and energy technologies, and (3) global environmental concerns associated with increasing energy use. The objectives of both the U.S and the developing countries can be addressed through clean, efficient, and economic energy supply, distribution, and end-use technologies. The purpose of the present section is to focus on the role of technology transfer and energy technology research, development, and demonstration (RD&D) in this overall context.

From the point of view of the U.S. national interest, a major objective is to get appropriate technologies—on both the energy use and energy supply sides—developed, adapted for developing country applications, and transferred into widespread use. A number of barriers and constraints must be overcome for this to be fully achieved. For example:

- In many countries, institutions for making and implementing decisions about energy technologies are poorly developed.
- The policy environment for energy technology decisions is often an impediment in trying to meet energy needs for development. For example, artificially low energy prices or tariffs on imported equipment can discourage the adoption of technologies that would be better for social and economic development.
- In many countries, debt burdens and political-economic uncertainties make it difficult to raise capital for investment in better energy technologies.
- In many cases, the energy technologies that are currently available are too expensive, too complicated, or not adequately adapted (eg., requiring frequent and complex maintenance, not able to be integrated with unstable power systems, needing highly trained operators) for developing country conditions.
- In some cases, the commercial viability of otherwise very promising energy technologies has not yet been demonstrated, and there is no apparent way to arrange such demonstrations.
- In general, the mechanisms for transferring technology-related information to and from developing countries are inadequate. Key decision-makers in the countries do not know enough about technologies that could help them, and we do not know enough about their special needs and perspectives.

5.2 Approaches to Technology Transfer

Strategies for overcoming these barriers often have to be developed on a country-specific basis. Several of the programs noted in §4 are demonstrating ways of overcoming them. For example, AID's Program to Accelerate the Commercialization of Energy Research (PACER) is a major initiative to improve the flow of information about innovative technologies to the power sector in India; and the Multiagency Working Group on Power Sector Innovation (MAGPI)—established with AID's encouragement—is helping to coordinate strategies for assistance and investment in a number of countries. DOE's CORECT Program has examined rural village electrification in the Dominican Republic, based on photovoltaic technology, to see how financial and skill barriers can be overcome.

Basically, the process should be straightforward although its effective implementation requires considerable effort and perseverance. A technology is developed or adapted which makes sense in a developing country context: it is inexpensive, robust, and appropriate for the nature and scale of particular energy needs. Local institutions—ideally, local private-sector entrepreneurs—learn enough about it to take the lead in marketing and operating it, helped by a constructive policy environment and appropriate technical and financial assistance from outside. The early applications are successful enough to encourage others, both within that country and elsewhere, and the technology becomes a significant self-sustaining part of the country's energy system.

One example of such a process at work has been the spread of energy-efficient cookstoves in Kenya. There, a collaboration between AID, the Government of Kenya, and others developed an improved stove—the Kenya Ceramic Jiko (stove)—which reduces charcoal use for cooking by 15 to 40 percent.[8] Local entrepreneurs have found the stove profitable to manufacture and sell; and current sales are estimated at 124,000-140,000 per year, with competition in the marketplace driving down the price of the stove. As a result, the consumption of wood resources in Kenya is being reduced, energy services are being provided more cheaply and efficiently to Kenyan households, and jobs have been created for Kenyan citizens.

A number of successful activities in transferring energy efficiency technology (both hardware and expertise) have taken place in recent years. As a result of AID industrial audit programs, investments have been made in several developing countries to reduce waste in existing industries. For example, more than 70% of energy audits undertaken through AID programs in Jordon have been implemented, leading to local investments of $12.3 million in energy conservation measures with an estimated annual savings of $9.7 million.[9] Similarly, AID programs to achieve industrial energy efficiency in Pakistan and load management in Costa Rica have resulted in high rates of implementation of recommended efficiency measures and rapid paybacks.

Three additional examples provide illustrations of the variety of approaches that can lead to successful technology transfer. AID has sponsored a project operating simultaneously in Indonesia, Malaysia, the Philippines, Singapore, and Thailand on energy efficiency in commercial buildings.[10] Its objectives are to establish building energy research capabilities in these countries and to support the development of national policies to bring about efficiency improvements. This project, by altering the policy environment in these countries, will foster the introduction of new technologies in commercial buildings, which consume 35% of total electricity generated in the region.

A second example is an innovative AID project in the Philippines, entitled "Technology Transfer for Energy Management" (TTEM), which is directed at supporting demonstrations of technology for energy efficiency in industry and buildings. This $5 million dollar program integrates a technical assistance effort (to assist in the choice and installation of technologies and to monitor the performance of the demonstrations) with a loan program. This is a unique effort to create an environment in which local businesses pay the cost of the demonstrations, but two types of incentives are provided: favorable interest rates on borrowed capital and technical assistance in carrying out the demonstrations and monitoring their performance.

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[8] H. G. Jones *"et al.," "Energy Efficient Stoves in East Africa,"* ORAU and ORNL for AID, October 1988.

[9] "Energy Conservation and Efficiency: Activities and Achievements Worldwide," H.C. Bailly, June 21, 1989.

[10] "ASEAN Buildings Energy Conservation Program," Lawrence Berkeley Laboratory, March 1988.

A third example is the considerable effort that has gone into finding appropriate markets for U.S. photovoltaic systems. In addition to CORECT, the U.S. government has supported design assistance activities in a variety of countries to provide the technical knowledge to implement photovoltaic technology. This has resulted in both opening markets for U.S. industry and benefiting developing countries, for whom photovoltaic systems are often excellent matches for energy needs in remote areas.

These successes notwithstanding, many of the best examples of the process in action often involve non-U.S. technologies. For technology developers and lenders from such countries as Japan, France, and Denmark, close cooperation between the public and private sectors gives them a competitive advantage over U.S. manufacturers and vendors. For instance, the concessionary financial arrangements they can offer are often impossible for U.S. vendors to match. Moreover, many observers of energy activities in developing countries have concluded that (with a few exceptions, such as photovoltaics and windpower) U.S. manufacturers have often paid less attention to developing specific technologies for developing country markets than have our competitors from other countries.

5.3 The Need for Energy Technology RD&D

Even where it is working, the process of energy technology transfer to developing countries appears to be leaving some critical gaps unfilled in the portfolio of energy technologies available to developing countries. For example, a country or a lender needing to generate electric power at moderate or larger scales (say, 100 MW or larger) and looking for realistic alternatives to fossil energy or hydropower will look in vain. (Nuclear power is an option for only a few developing countries at the present time.) Similarly, a country or a lender wishing to provide affordable refrigeration services to a developing country without increasing global chlorofluorocarbon (CFC) emissions will find nothing currently available.

These considerations lead to a recognition of the importance of energy technology research, development, and demonstration for developing countries. Such energy RD&D is not the present responsibility of any agency of the U.S. government, nor of any other institutions involved significantly in energy assistance to developing countries. Energy RD&D needs lie in four related areas:

(1) Adapting available technologies

Many seemingly attractive technologies are already available, but are not being used because the technologies need to be adapted to developing country conditions. Typically, for example, equipment needs to be able to operate with minimal maintenance and to withstand fluctuating voltages in power grids.

(2) Developing new or improved technologies to fill gaps in the portfolio of options

Although the energy technology portfolio has been considerably enhanced by the energy R&D investments of the 1970s and 80s, there remain a number of gaps which limit the choices available to a developing country. In the case of electric power generation, as discussed above, there is a great need for alternatives to fossil-based power and more efficient fossil energy conversion.

(3) Demonstrating innovative technologies

Innovative technologies, whether adaptive or new, need to be demonstrated at a sufficient scale to establish operating parameters and costs so that the countries and lending institutions will consider the technologies to be commercially viable. As noted in §4, lending

institutions tend to be conservative by nature and, in addition, do not fund the development and demonstration of innovative technologies.

(4) *Establishing and improving in-country energy R&D capabilities*

In-country energy R&D capabilities can help the country (1) evaluate and adapt imported technologies and (2) make effective use of other R&D being conducted in the country. There are often R&D projects that are best done using capabilities in developing countries. Finally, technology transfer and commercialization are often aided by the active involvement of in-country researchers.

An obvious problem with adapting existing technologies or developing new ones is the location-specific nature of many energy applications. Attempting to adapt or develop technologies for 70 or 80 different country situations would be unrealistic. However, criteria could be developed to help establish priorities. China and India, for instance, include nearly half of the world's population and account for a major share of anticipated increases in CO_2 emissions over the next half-century. Focusing on a few countries such as these would be an efficient way to address U.S. objectives. Another possible approach is to concentrate RD&D resources on a particular product of anticipated widespread applicability.

5.4 Examples of the potential role of energy RD&D

For purposes of illustration, two examples (of many possible ones) are given of situations in which energy RD&D, in combination with addressing institutional barriers, could lead to more effective energy supply and use.

5.4.1 Example: Compact Fluorescent Lamps in India

Incandescent lamps are widely used in villages in India and are a major energy consumer. Compact fluorescent lamps fit in the same sockets as the incandescents, and use only 20% of the power to give the same light output. Increasing demand for electrical energy could be met in part by replacing high-use incandescents by compact fluorescents at an estimated cost of conserved energy that is about 5 times less than the cost of obtaining additional electricity. However, widespread replacement is unlikely to occur until both technical and institutional problems are addressed.

At the individual lamp level, the electronics of the compact fluorescent need to be adapted to handle wider voltage fluctuations that are experienced in the U.S. At the system level, care must be taken to ensure that the electrical characteristics of the lamps do not adversely affect the power distribution system. Technological developments in either the lamps or the power grid could address the system problems. Such developments would need to be followed by a demonstration on a reasonably large scale.

Technological improvements will not be sufficient to assure actual use of compact fluorescents since the price of electricity is subsidized so heavily that the lamps are not economic from the viewpoint of the individual consumer. While raising the price to reflect the actual cost would remove this particular barrier, there is another approach which does not require such a change. The utilities could purchase the lamps and distribute them to consumers for free or a nominal charge. The consumer benefits from reduced electricity costs, and the utility benefits by having power available for other purposes at a cost that is small compared to new capacity.

5.4.2 Example: Integrated Biomass and Gas Turbine Facility

Biomass has been estimated to account for roughly one-third of total energy use in developing countries. However, the use of biomass is often very inefficient (e.g., for cooking), and is at least partially responsible for deforestation. Improvements in the efficiency of current uses have obvious benefits. Further, an argument can be made that a centralized high-efficiency biomass-to-electricity conversion facility could (1) provide electrical power at competitive costs, and (2) encourage the renewable use of biomass (e.g., woody crops) grown in the near vicinity of the facility in order to minimize transportation costs. There are a number of candidate technologies, including direct combustion. Discussed here is an integrated facility which converts biomass to gas for use in an intercooled steam-injection gas turbine.

Turbines derived from jet engines for commercial aircraft have considerable potential to be a high-efficiency and cost-competitive source of electricity. Much of the work to date on turbines coupled to coal gasifiers is directly applicable to biomass. Further, any country with a commercial airport already has the requisite expertise for maintenance of the turbine. Recently, steam injection (with the steam generated from the exhaust gases) has been demonstrated to substantially increase the power output and slightly increase the efficiency, which reduces the cost per unit of electrical power. A next step, intercooling, requires additional development but would again increase the efficiency and reduce the unit costs.

Biomass is inherently easier to gasify than coal, and does not have the complication and expense of sulfur removal. However, technical developments will be needed to match gasifiers to the variety of potential sources of biomass, and to ensure that the gasifier output is compatible with the turbine.

Following the necessary technical developments, demonstrations would be needed to establish operating parameters and actual costs. Great differences exist among different regions in the nature of available biomass, infrastructure to handle biomass, amount and suitability of available land, and the competing uses for this land. Agricultural residues might serve as the source of biomass during the demonstration and early implementation phases.

5.5 Partial list of needed energy technologies and capabilities

Many other examples could be cited of technologies that would address U.S. and developing country objectives and that could be advanced by energy RD&D. Listed here are rather broadly-stated energy needs of developing countries and particular technological options which could address those needs. The list is intended to provide a flavor for the wide range of possibilities, and is not intended to be detailed, exhaustive, or imply a prioritization.

- Moderate-scale (100 MWe, within a factor of two) electrical generation facilities using energy sources other than fossil fuels and hydropower.
  - — Geothermal power plants for countries with that resource
  - — Advanced gas turbines coupled to coal gasifiers (details in §5.4.2)
  - — Modular nuclear power plants that are passively safe and have diversion-resistant fuel cycles
- Efficient and clean coal conversion for electrical generation, particularly for countries (such as China and India) with large coal reserves of varying and/or poor quality coal.
  - — Fluidized bed combustion and integrated-gas combined-cycle combustion

- Beneficiation technology for high-ash content coal

- Small scale (1-20 MW) electrical, shaft power, and combustible material facilities for rural areas, especially those without access to the power grid. Must be simple to install, operate, and maintain.
  - Wind turbines, photovoltaics, solar thermal
  - Biomass converters (gasifiers, briquetting machines)
  - Advanced diesel generators
- More efficient and lower polluting end-uses devices in order to reduce demands on energy supply, and improve health and environment.
  - Cookstoves with improved efficiency and reduced emissions
  - Moderate-sized (as compared to U.S. market) and efficient domestic refrigeration units, preferably with non-CFC insulation and refrigerants
  - Compact fluorescent lamps as efficient replacement for incandescent lamps in high use situations (details in §5.4.1)
- Energy-efficient buildings to reduce demands on energy supply. Residential and commercial building energy use are the fastest growing sectors in the majority of developing countries.
  - Climate-dependent design and construction strategies to reduce intrinsic energy demand, especially for mechanical cooling (shading, natural ventilation)
  - Advanced lighting systems
  - Techniques for control of optical and thermal energy flow through windows
- Improved electrical distribution systems, which are presently prone to fluctuating voltages and significant transmission losses (20 - 30% as compared to about 8% for the U.S.)
  - Electronic systems for load management, dispatching, optimization of distribution network, metering and billing, and detection of losses and thefts in transmission and distribution

These and other energy technology research and demonstration projects need to be conducted in an environment in which energy policy decisions support good energy choices, expertise among planning and technical personnel in the developing countries is adequate, and access to the technologies is reasonably assured. As such, it will be important to undertake training programs, develop and support policy analysis, and assure U.S. private sector participation in the endeavor. Thus, in addition to energy technology RD&D of the types indicated in this chapter, a balanced program with a full range of supporting activities to assure technology transfer is needed. Examples of such activities might include analysis of specific policy options to promote energy efficiency, assistance in electric utility planning, training programs in the application of key energy technologies, and a variety of similar efforts that promote a better informed energy policy and technology community in developing countries. For the specific technologies for which RD&D efforts are actively pursued, involvement of suppliers early in the process, identification of barriers to trade, and assessment of ways of overcoming such barriers needs to be built into the process.

6. A Possible DOE Role

Because it is not the present role of any agency or institution, there is no i major U.S. effort to organize and lead necessary RD&D to supply better energy technologies for developing nations. In the previous sections, we have explained that RD&D is required to adapt existing technologies to the particular conditions in developing countries and on occasion to develop new ones which are presently not available. DOE is the federal agency with the technical experience, knowledge and resources to meet this requirement.

There are many ways a DOE contribution to the national effort might be organized. Certainly, it must be a partnership with other U.S. agencies such as AID, Departments of State and Commerce, with the U.S. private sector, with multilateral lending organizations such as the World Bank and the regional Banks, with the United Nations institutions, with other industrialized countries, and with the governments and R&D communities in the developing countries themselves.

The job is so enormous, however, that priorities must be defined. Below, we suggest some of the considerations for using the expertise of DOE to focus on assisting developing countries in the the selection and application of improved energy technologies.

6.1 Country-Specific Emphasis

The choices some countries make are more critical to the U.S. interests than others. This is certainly true, for example, regarding climate change. The big three — China, Brazil, and India — dominate with respect to present and future CO_2 emissions. These countries are also important to the United States for trade and strategic reasons. A possible strategy is to concentrate technology development and exchange efforts on countries such as these. As noted in the previous section, U.S. technology support should include helping to build in-country RD&D capabilities, training, providing information, helping analyze policy alternatives, as well as conducting relevant RD&D to provide better technologies.

6.2 Technology-Specific Efforts

Some technologies may be very important for many countries. We have provided examples throughout the text of technology RD&D efforts that could provide potentially valuable benefits to developing countries. A careful analysis is needed to establish the areas of energy technology research, adaptation, development, demonstration, and transfer that are likely to yield the greatest benefits. This could provide the basis for initiating programs in several countries and assisting the U.S. private sector in making successful technologies more broadly available to these countries.

6.3 A Comprehensive Information Dissemination System

Developing nations have tough decisions to make, and they are faced with a bewildering set of options and potential purveyors of assistance. The U.S. could provide a one-stop information source, the purpose of which is to provide credible information and tools (such as economic models and technical performance models) for comparative analyses. This system could be tied into all of the organizations and countries active in providing technical and financial assistance on energy. This information function would also assist in setting up joint coordinated and cooperative projects. It might also encourage the development of RD&D specialty institutions in developing countries.

DOE capabilities are such that it could play a lead or support role in establishing such a system, depending on the willingness of other agencies to undertake this endeavor. Whatever agency assumes the leadership, it will be important that all organizations involved in energy RD&D and energy assistance to developing countries participate actively in establishing such an information system.

6.4 The Next Steps

Considering the growing importance of developing nations to oil markets and the global environment, and as markets for U.S. technologies, the topic of energy technologies for developing countries is of growing importance. DOE has substantial capabilities to contribute to solutions of major global energy problems. It does not as yet have a clear mandate, mission, or sufficient programs to become a major player in working with developing countries.

In our judgment, the next step is for DOE, as part of its National Energy Strategy, to reassess its role in providing energy technology RD&D and technology transfer to developing countries. In order to assess these issues, it is appropriate to hear various views on this topic through the public hearing process. Additional efforts to develop more concrete plans will be necessary to establish major new programmatic activities related to energy technologies for developing countries, if the DOE is to play a significant role in this area.

Appendix A

U.S. Bilateral and Multilateral Agreements on Energy Cooperation with Developing Countries

Summary of Bilateral Agreements			
Participating Country	Project Description	Started	Annual Funding* ($k)
Brazil	Development of technology for the underground coal gasification at Triunfo in Rio Grande do Sul to produce synthetic gas	1984	-0-
	Technical information exchange in underground coal gasification	1985	
	Feasibility study for underground coal gasification at Triunfo (with TDP)	1986	
	Cooperation in biomass, alcohol fuels, and energy planning/analysis under presidential science and technology initiative	?	-0-
India	Cooperation in underground coal gasification — R&D activities	1987	-0-
South Korea	Technical coal and laboratory information exchange (PETC)	1981	-0-
Mexico	Exchange of scientific and technological information in petroleum R&D	1983	-0-
	Computer modeling codes and techniques for enhanced oil recovery	1985	100
	Mayan crude characterization and correlations for refining operations	1987 ?	
	Thermodynamic studies of petroleum	1987 ?	
	Coal/oil coprocessing	1986 ?	
	Geothermal energy R&D cooperation	1986	-0-
PRC	Cooperation in the field of fossil energy R&D	1985	-0-
	Enhanced oil recovery	1985 ?	

(Continued on next page.)

Summary of Bilateral Projects (Continued)			
Participating Country	Project Description	Started	Annual Funding* ($k)
Venezuela	Exchange of technical information and development of new techniques in the characterization of heavy crude oils	1980	-0-
	Cooperation in university, energy technology center, and national laboratory research programs in enhanced oil recovery and coal preparation, combustion, and related technology	1980 1982	
	Enhanced oil recovery process technologies	1980	-0-
	Cooperation in modeling re subsidence due to fluid withdrawal	1983	25
	Training of Venezuelan petroleum engineers at Naval Petroleum Reserve Facility	1984	-0-
	Geochemistry technology exchange and modeling on petroleum	1985	-0-

Summary of Active Multilateral Projects			
Participating Country	Project Description	Started	Annual Funding* ($k)
Egypt	Enhanced oil recovery fundamental studies, laboratory research, and field tests, specifically residual oil saturation, gas injection, and thermal recovery	1979	-0-
Jordan Nigeria Trinidad and Tobago	Exchange of heavy crude and tar sands technical information	1979	25-50

* In kind contributions of staff effort are not included and represent the major portion of the U.S. expense.

Appendix B

The Committee on Renewable Energy Commerce and Trade

The Committee on Renewable Energy Commerce and Trade (CORECT) is the principal international technology assistance program in the renewable energy area. CORECT is an interagency working group that facilitates the use of U.S. renewable energy products and resources around the world. Established by the Renewable Energy Industry Development Act of 1983, CORECT includes representatives from 14 member agencies. CORECT is chaired by the Secretary of Energy; day-to-day management is provided by the Director of the DOE Photovoltaic Energy Technology Division.

The CORECT serves as the vehicle to bring together developing country officials, donor agencies, and U.S. renewable energy firms in instances where those technologies make technical, economic, and institutional sense. By assisting decision-makers to consider and incorporate renewable energy technologies into their planning processes, the CORECT provides developing countries with an energy alternative that is environmentally acceptable, conducive to local manufacture, and contributes to economic development, industrial growth, and energy supply security objectives.

The CORECT is divided into four subcommittees that conduct activities in their respective areas of specialty: education, technical competitiveness, market development assistance, and trade policy. There are also two special task forces. One task force examines available financing sources and recommends measures to improve access to financing by renewable energy firms, and the other identifies conferences, meetings, and trade shows for CORECT participation.

The Education Subcommittee provides decision makers in the United States and overseas with technical and economic information about renewable energy. The Technical Competitiveness Subcommittee investigates ways to improve the technical and cost competitiveness of U.S. renewable energy products, and provides technical assistance to potential users of these products. The Market Development Assistance Subcommittee works to improve the coordination of federal export assistance programs. The Trade Policy Subcommittee identifies the trade barriers that inhibit exports of U.S. renewable energy products and services. CORECT's Staff Director coordinates three services that support these subcommittees: the Analysis Service, based at SERI; the Export Council for Renewable Energy's Industry/Trade Activities Service; and the Design Assistance Center (DAC), implemented through Sandia National Laboratories.

CORECT has maintained systematic efforts to incorporate U.S. renewable energy products and issues into the long-term plans of foreign markets that offer the most significant opportunities, including foreign utilities. CORECT has been able to demonstrate that renewables are a viable, competitive option for foreign utility planners and government decision-makers. It has helped federal assistance become more targeted and complementary to individual industry efforts by working closely with the renewable energy industry. CORECT takes advantage of the existing international assistance framework of donor agencies and development institutions to inform potential users about the U.S. renewable energy industry. This accelerated education is particularly important for markets in developing countries. CORECT also utilizes the "reverse trade mirror" concept. This involves bringing foreign buyers to the United States, exposing them to U.S. operating experience, and reinforcing the technical leadership of U.S. companies.

The newest activity within CORECT is the Integrated Electric Utility Program (IEUP). The objective of this effort is to assist developing countries in accelerating electrification progress, and to strengthen their institutional capability to implement decentralized power projects, especially by using renewable energy technologies. The Program emphasizes working with the utility community in the developing country. Within that environment, the Program provides the technical background, tools, and perspective necessary to incorporate renewable decentralized options into the generation mix. CORECT is working with U.S. electric utilities and the renewable energy industry in developing and executing this program.

Appendix C

DOE Fossil Energy Program with Developing Countries

International Agreements

- R&D Memoranda of Understanding with Brazil, India, South Korea, Mexico, PRC, and Venezuela (bilateral) and Egypt, Jordan, Nigeria, and Trinidad and Tobago (multilateral) (detailed on summary listing of bilateral and multilateral agreements)
- Technical Cooperation Arrangements for deployment of clean coal technology (CCT) — executed with Costa Rica, under consideration with Chile, Malta, and Thailand

[Cooperative energy R&D activities in the developing countries have been limited for the most part to information exchange and assignments of developing country personnel.]

Study Programs

- International Markets for and Competitiveness of U.S. Clean Coal Technologies
- Pacific Basin Coal Trade Issues (status, innovative transport, and blending)
- Potential Markets for Small Coal-Fired Combustors in Organization for Economic Cooperation and Development (OECD) Countries
- Asia-Pacific Coal Project — East-West Center (Hawaii)
- International Coal Technology Monitor (status of coal technology developments)
- International Coal Logistics Personal Computer "What If" Program for Economics of Delivering U.S. Coals

[Current funding level of $1.1 million includes $750,000 for joint prefeasibility studies with TDP and AID (listed in Other Efforts) and $400,000 for contracted studies, only a portion of which is related to developing countries.]

Other Efforts

- DOE/TDP/AID program of joint agency financial support for prefeasibility studies by U.S. companies for international energy trade opportunities ($750,000/DOE portion only)
- Participation in United Nations/Economic Commission for Europe Coal Committee — coal codification/classification and coal trade and statistics subcommittees
- Recent Clean Coal Technology Presentations in Dominican Republic and Thailand
- Compilation of *Guide to Federal Export Assistance Activities Applicable to the U.S. Coal* and *Coal Technologies Industry*: includes assistance programs and specific contacts in export counseling and assistance, overseas market development, trade opportunities identification, feasibility studies, export financing, insurance, export licensing, trade regulations, and training and technical assistance
- Development of an industry directory —
  Directory of U.S. Coal and Coal Technology Resources
- Assistant Secretary (Fossil Energy) chairs the DOE Coal Export Initiative Program which includes intradepartmental coordination and cooperation with the Departments of State, Commerce, and Transportation, the U.S. Trade Representative, TDP, AID, U.S. ExIm Bank, OPIC, and the Office of Management and Budget

Appendix D

Projects Directly Related to Energy Technology and Energy Assistance to Developing Countries at DOE National Laboratories

ARGONNE NATIONAL LABORATORY

PROJECT TITLE	TOTAL FUNDING in thousands of dollars (FY 86, 87, 88)	FUNDING SOURCE
Environmental and International Comparative Analyses for Selected Clean Coal Technologies	**$350**	**DOE/FE**

Project Description: Study areas include: the characterization of specific demand centers, including Turkey, the Peoples' Republic of China (PRC), Morocco, and Pakistan, representative of expanding international markets; the identification of research, development, and demonstration initiatives of countries competing with the U.S.; the identification of barriers to international competitiveness; and the characterization of U.S. and competitive technologies believed to have significant potential in the international market. The objective is to impact the U.S. CCT demonstration program and the direction and content of its research and development, with respect to international markets.

Characterization of Small Combustors in Industrial and Residential/Commercial Applications	**$230**	**DOE/FE**

Project Description: Market niches are identified, defined, and characterized for international applications of innovative U.S.-developed advanced technology for small combustors in industrial and residential/commercial settings. Where coal use is currently large or growing, such as in Turkey, industry structure, environmental regulations, fuel availability and use, and fuel supply infrastructure are highlighted. The potential for growth in these market segments is assessed together with regulatory and environmental impediments.

Pacific Basin Coal Trade Issues	**$315**	**DOE/FE**

Project Description: The objective is to identify, define, and evaluate those coal trade factors which can effect the competitive position of U.S. coal in the Asian Pacific Basin market. The current emphasis is on innovative approaches to reduce transport costs of U.S. coal exports to the Asian Pacific Basin.

Nuclear Technical Assistance	**$150 (FY 87-89)**	**DOE/NE**

Project Description: ANL has provided nuclear technical assistance to various countries, and, specifically, to countries that have cooperating laboratory agreements.

Nepal Coppice Reforestation Project	**$1,850 (FY 87-89)**	**US AID**

Project Description: In 1986, Argonne began an applied forestry research and demonstration project aimed at reforestation, fuelwood, and fodder production in the mid-hills of Nepal. The project's emphasis is on the selection and propagation of multipurpose tree species. The project includes a sociocultural dimension which identifies local species preferences and facilitates the adoption of systems using multipurpose tree species.

Advanced FE Technologies for International/Regional Development	**$200**	**DOE/PETC**

Project Description: The objective is to identify, evaluate, analyze, and develop market opportunities in power generation and industrial applications for U.S. fossil fuel technologies in India, Pakistan, and Puerto Rico. This work builds upon collaborative efforts initiated by PETC, especially with US AID and the Government of India.

Determinants of Effectiveness	**$525**	**DOE/FE**

Project Description: Decision-analysis methodology and software for ranking and comparing international collaborative research and development activities has been developed. Developing countries are being considered for bilateral collaborative agreements.

Technical and Policy Analysis for Fossil Energy International Program (LDC Initiative) — $590 — DOE/FE; $50 — AID

Project Description: The project undertakes a rigorous examination of the fossil energy development needs and interests in selected countries—Costa Rica, the Dominican Republic, and Thailand—with respect to their overall national development activities, plans, and policies. A systems analysis is planned to determine the feasibility and appropriateness of the potential projects in the existing/planned energy system of each country using private funding.

Private Power Opportunities in Developing Countries — $100 — AID

Project Description: The project will assist AID identifying and evaluating market opportunities for U.S. fossil-fuel technologies in private power sector projects of interest to selected developing countries.

Energy and Power Evaluation Program (ENPEP) — $100* — DOE/IE; DOE/NE

Project Description: This microcomputer-based energy planning package, intended primarily for use by developing countries, consists of eight technical modules that treat various components of energy planning, including energy demand, energy demand/supply balancing, electrical load forecasting, electrical generating system expansion, and environmental impacts. The package is currently being field-tested in several countries under sponsorship of the International Atomic Energy Agency (IAEA) and the World Bank. It has been released to IAEA for distribution.

Energy Planning Methodology for Egypt — $103 — AID

Project Description: Working with the Egyptian Organization for Energy Planning (OEP), ENPEP has been installed on OEP microcomputers and a three-week training session has been conducted. In addition, several seminars on energy systems were prepared and presented as part of an OEP conference.

Energy Planning Training Courses — $300 — DOE/IE; DOS/IAEA

Project Description: ANL has conducted 11 training courses for 293 energy planners from 54 countries over the period 1978-1989. Eight electric system expansion planning courses have held (nine-week duration) and three energy demand analysis courses have been conducted (five-week duration).

In 1989, the electric system expansion planning course is making use of the microcomputer version of the mainframe computer model (Wien Automatic System Planning Package, WASP-III) that was featured in previous courses. Countries attending the September 18-November 17, 1989 course include: Bolivia, Bulgaria, Hungary, Kenya, Nigeria, Pakistan, Philippines, Turkey, Venezuela, and Yugoslavia.

Technical Assistance to IAEA — $180 — DOE/IE; DOS/IAEA

Project Description: Technical assistance to a number of countries was provided supporting IAEA projects. Recently, this assistance included ENPEP installation and training in Indonesia and Malaysia. ANL staff have also provided technical assistance and lectures at IAEA regional training courses in the PRC, Malaysia, Morocco, Argentina, Indonesia, and Yugoslavia.

Energy Planning: Methods of Analysis and Training — $285 — World Bank

Project Description: The World Bank's Energy Planning Project is intended to strengthen the national planning capabilities of the participating countries. ANL conducted a four-week training course on energy planning methods for nine countries and carried out detailed analyses of the long-run marginal cost of electrical generation with three countries (Algeria, Cyprus, and Hungary). ANL has also conducted studies and provided training to several other countries (Sri Lanka, Pakistan, Poland, and Yugoslavia) on other World Bank projects.

* $600,000 is the total funding since FY 1984.

PROJECT TITLE	TOTAL FUNDING in thousands of dollars (FY 86, 87, 88)	FUNDING SOURCE

Parameters of Future Energy Demand in Developing Countries — $420 — DOE/IE and Various Oil Companies

Project Description: The purpose of this research is to understand the forces that shape the growth of energy demand in the less-developed countries (LDCs). This work presents a complete analysis of over 15 developing countries. This includes a detailed description of each sector over time, review of important trends in structural change or composition, conservation, and fuel switching, the collection of data on factors that affect energy growth, analysis of data to show comparison among key countries/regions of the world, and preliminary projections and sensitivity studies of LDC energy demand to the year 2100.

Long Term Energy Use Related to Global Warming — $80 ($325 FY89) — EPA

Project Description: This project assists the Environmental Protection Agency in the assessment of the environmental effects of global climate change and the choices the international community may need to consider to both adapt to and limit potential global warming. LBL is helping to characterize technology and improve projections of scenarios of global energy use. This work is (1) determining recent trends in efficiency and structure of OECD energy demand, (2) extending the analysis to Comecon countries, and (3) extrapolating these trends well into the next century.

Trends in LDC Energy Demand — $216 — DOE/CE and DOE/PE

Project Description: The increasing demand for oil in the LDCs represents both a threat to the security of oil supply to the U.S. as well as an opportunity for improvement in trade. This project studied the trends in oil demand and production capacity in the LDCs and assessed the fraction their petroleum production that could be exported. Specifically this project covered 1) long-term energy and oil demand with an emphasis on transportation; 2) short-term oil demand and changes; and 3) indigenous oil demand threat to oil exports: Indonesia, Mexico, Nigeria and Venezuela.

LDC Energy Models in a Global Context — $100 — DOE/PE

Project Description: In the analytical community, there is no global energy model that explicitly accounts for and projects LDC energy use at the level of detail devoted to OECD countries. This project will develop a framework that will, for the first time, explicitly model LDC energy demand and supply and develop new modeling concepts and methodology.

Global Climate Change: Policy Studies — $25 — DOE/EH

Project Description: This project establishes a data base and analytic tools to provide a basis for a long-term policy research agenda on energy and global warming issues. The project involves several separate tasks, which include: expanding LBL's data bases on energy demand, supply, and prices in developing countries, with emphasis on electricity and biomass and studying China as a contributor to global CO_2 and other greenhouse emissions. In addition to these research tasks, LBL is actively participating in organizing major workshops on global warming issues being carried out by the University of California.

ASEAN Energy Conservation in Buildings — $2,350 — AID

Project Description: Since 1981, LBL has performed research in support of policies to reduce building energy use throughout the ASEAN countries (Singapore, Indonesia, Malaysia, Philippines, and Thailand). The project also involves supporting research, conducted by Southeast Asian researchers in their countries, on different aspects of energy use in commercial buildings. In addition, the project supports conferences and training courses in aspects of energy use in buildings and building energy conservation policy development for the ASEAN region. The major long-term aim of the project is to promote policy reform that will lead to increased energy efficiency in commercial buildings.

Energy Demand Studies in China — **$155** — **DOE/PE**

Project Description: This project is intended to improve understanding of current trends in China's energy markets and Chinese energy policies that will affect the future shape of energy demand in that country. In order to promote this understanding, the Energy Analysis Program at LBL is collaborating with institutions in the U.S. and abroad and help organize and participate in workshops and conferences in China. Participants will include energy researchers, government experts and industry specialists from China and the United States.

Renewable Energy Applications and Training Project — **$85** — **ORNL**

Project Description: LBL assisted ORNL with an assessment of experiences in developing countries with applications of renewable energy technologies. Specifically: (a) evaluation of renewable energy project experiences in developing countries; (b) evaluation of technology experiences in developing countries; and (c) assessing the implications of oil price scenarios for renewable energy options. This project also involved power systems planning activities, emphasizing applications of least-cost planning approaches in AID-assisted countries and small power systems planning for rural areas in developing countries, emphasizing data gathering about recent and current needs and experiences.

Residential Energy Use and Conservation in Venezuela — **$57** — **DOE/CE and Ministry of Energy and Mines**

Project Description: The project has focused in its first year on the analysis of energy use patterns in the residential sector of the city of Caracas, including the development of household surveys, and the analysis of natural gas substitution and energy conservation potential. LBL will relate the results of this analysis to specific recommendations of policy instruments designed to improve the efficiency of energy end-use in the sector, and expand survey and analysis to a larger sample of cities to insure the possibility of extending the results of this study to the different climate regions of the country.

Impact on the U.S. of Changing Oil Use in Key Developing Countries — **$50** — **DOE/FE**

Project Description: The project provided DOE with analysis of the important regions where substantial changes in oil and energy demand patterns are occurring. The project first analyzed the stability of the decline in oil use in the major oil-importing developing countries and several large oil exporting developing countries. Second, the analysis extended to countries in Africa and the Middle-East of interest to the U.S., for purposes of identifying the magnitude of the continued burden of energy costs and the ways in which U.S. policies can reduce that burden.

World Energy Demand Initiative — **$50** — **LBL**

Project Description: The long term objective of this project was to better understand energy demand in industrialized and developing countries in a framework consistent for global scientific understanding of the linkage of energy demand to economic activity in these countries. This objective was achieved through a series of meetings in which international energy experts from Europe, Asia and Latin America focused on various relevant topics.

LOS ALAMOS NATIONAL LABORATORY

PROJECT TITLE	TOTAL FUNDING in thousands of dollars (FY 86, 87, 88)	FUNDING SOURCE

Central Energy and Resources Project — **$13,060** — **US AID**

Project Description: The goal of the Los Alamos Energy and Resources Project is to improve the economic condition in Central America and help create employment through increased and more efficient utilization of the region's rich energy and natural resource endowment. This is to be accomplished by introducing new technologies and assessment techniques into Central America that will allow each of the participating countries to better analyze their current and future energy needs, by developing nontraditional sources of energy, and by more effectively utilizing the energy and mineral resources found in the region. The components of the program along with brief descriptions are given below:

Energy Planning Assistance — The objective of this component is to work with Central American government energy planning organizations to improve their energy planning capabilities. Improved national energy planning is expected to contribute to overcoming energy problems through more efficient energy use, investment, and pricing. The component started with an energy situation analysis activity with the purpose of providing the latest data on the energy sector in Central America. Following the energy situation analysis, the activities included building a computerized database of relevant economic and energy data, transferring the database to the countries in the region along with computer software and hardware, instructing the energy planners in each country on the use of the computer models and databases, and building regional institutional capabilities in energy planning methodologies through workshops and individual training. Using the above techniques, Los Alamos is working with each countries' planning organizations to provide energy planning assistance on specific energy topics of interest.

Direct Heat Applications of Geothermal Energy — This component is designed to identify the potential in Guatemala for the use of low- to medium-temperature fluids to provide process heat in agricultural, commercial, and industrial applications. Following a feasibility study, Los Alamos has provided the technical assistance and materials needed to construct a small food dehydration facility in Zunil, Guatemala, that uses geothermal steam as the energy source for the air drying. Labor for building the plant was provided by INDE (the national electric utility) and by personnel contracted by the Gremial de Exportadores de Productos No Tradicionales under a contract with LANL. This facility contains many elements required for a commercial scale geothermal dehydration facility and thus can be used to demonstrate how different products can be dried, to produce samples of dried products for marketing purposes, and to provide a facility that can be used for hands-on training. Construction of the plant is complete and efforts are underway to transfer the plant to the private sector.

Peat Resource and End-Use Assessment — Activities as part of this component were concentrated in two countries—Costa Rica and Panama. The peat end-use assessment program in Costa Rica, a joint program between LANL and RECOPE (the national hydrocarbon company), consisted of four interrelated activities: to characterize Costa Rican resources, analyze peat end-uses, educate the private sector in its usage, and train local counterparts in peat development technology. Two peat deposits (El Cairo, Los Chiles) were identified and characterized. Responsibilities for the program were turned over to RECOPE. The Panama peat program was to characterize Panamanian resources, analyze the feasibility of a peat-fired plant for electricity generation, and educate local geologists in sampling and assaying. A large and high quality deposit at Bocas del Toro in northwestern Panama was discovered. Also, some assistance was given to prepare a prefeasibility study for the power plant and training was accomplished in resource evaluation techniques. All activities were discontinued in Panama due to political difficulties.

Geothermal Resource Development — This component deals specifically with identifying and assessing geothermal resources that have not received a significant amount of prior analysis or investigation. It is focused on providing technical assistance in the exploration and prefeasibility assessment stages of geothermal development, including reconnaissance scale geological and geochemical investigations and the drilling of geothermal gradient coreholes. The major efforts have been expended in Honduras and Guatemala. In Honduras, Los Alamos has worked with ENEE (the national utility) and the USGS to evaluate the potential of six geothermal sites. After extensive geological and geochemical studies, the Platanares site was identified as having the highest potential for electricity generation. In Guatemala Los Alamos has been providing technical assistance to INDE (the national utility) in performing a prefeasibility study of the Tecuamburro volcano in the eastern part of Guatemala.

Geothermal Field Development — This component deals specifically with a geothermal resource after discovery and with improving the understanding and definition of the characteristics of the reservoir. It is intended to assist the countries of Costa Rica, El Salvador, Guatemala, and Honduras in the development of their most promising fields. Geothermal fields that have been investigated as part of this component include Miravalles (Costa Rica), Ahuachapan/Chipilapa (El Salvador), and Zunil (Guatemala). Early in the program, a state-of-the-art well logging truck and downwell tools were purchased for use in the region. This equipment was patterned after equipment developed at LANL for the Hot Dry Rock Project and has allowed the successful monitoring of downwell temperatures, pressures, and casing diameters, as well as the collection of brine samples for geochemistry at high temperatures. These measurements have been particularly useful in developing reservoir models for each geothermal field, as well as informing the utility responsible about the condition of the wells.

Mineral Resource Assessment — The primary objective of this component was to stimulate the growth of the Costa Rican mining industry by providing geochemical and geological data to encourage future mineral exploration. A further use for the data is land-use management and planning. This component is a cooperative effort between Los Alamos, the U.S. Geological Survey, the Ministry of Energy, Mines, and Natural Resources, and the University of Costa Rica. The work has been completed and included a Preliminary Mineral Resource Assessment Folio with a detailed study of Costa Rica's gold belt, stream-sediment sampling manual, a geochemical atlas of San Jose and Golfito areas, and both on-the-job and formal classroom training. The models and geochemical maps generated under this component have served to identify areas with favorable mineralization characteristics. All the available data were presented in an international gold conference conducted in 1988.

LANL/ININ Sister Lab	**$150**	**DOE/NE/f1**

Project Description: There is a "sister laboratory" cooperation between Los Alamos National Laboratory (LANL) and the Instituto National Investigationes Nuclear of Mexico (ININ). This involves nuclear technology transfer in activities of mutual interest including ININ responsibilities to support safe handling of low level radioactive wastes, emergency response, and safety of the LaGuna Verde nuclear power plant.

OAK RIDGE NATIONAL LABORATORY

PROJECT TITLE	TOTAL FUNDING in thousands of dollars (FY 86, 87, 88)	FUNDING SOURCE
Power System Strategies for Developing Countries	**$950**	**A.I.D.**

Project Description: This activity is focused on identifying and implementing innovative alternatives for meeting growing electric power needs in developing countries, given serious capital and environmental constraints. It addresses a variety of issues, including institutional performance improvement, power system efficiency improvement potentials, and rural electrification strategies. One accomplishment has been helping to establish the Multiagency Working Group on Power Innovation (MAGPI), an international group which seeks information exchange and collaborative project development to help solve emerging power system problems.

Integrated Energy Planning and Policy Development	**$1,250**	**A.I.D., DOE ORNL**

Project Description: This activity emphasizes energy planning for developing countries (strategy development and implementation rather than tool development), energy policy reform, and technology transfer strategies. It includes technical assistance to A.I.D. offices and missions related to program planning and strategy development.

Environmental Management in Developing Countries	**$910**	**A.I.D., DOE, SSRC, Others**

Project Description: The focus of this work is on environmental management strategies for the energy sector in developing countries, emphasizing responses to the global climate change issue. It includes efforts to design microcomputer-based decision support tools to assist in project evaluation, in collaboration with A.I.D., the World Bank, and others.

Energy Project Feasibility Assessment, Design and Evaluation	**$465**	**A.I.D.**

Project Description: This includes a range of technology and policy assessments, such as contribution to an assessment of a proposed oil shale power facility in Jordan; project design assistance to A.I.D. offices and missions; and project evaluations in such countries as Egypt, Ecuador, and Sudan.

Energy for Rural Areas of Developing Countries	**$300**	**A.I.D.**

Project Description: This activity is focused on identifying energy technologies and deployment strategies to improve energy-supply infrastructures in rural areas of developing countries, with a particular interest in dispersed "minigrids" and innovative approaches to meeting energy needs for water lifting and sanitation. Work related to rural electrification is included under the power system category above.

Renewable Energy Applications in Developing Countries	**$1,050**	**A.I.D., DOE**

Project Description: This work emphasizes the development of "bankable" (i.e., implementable) renewable energy projects with private sector participation. It includes support to the interagency CORECT program, addressing such issues as the financing of small-scale technology use, and a recent comprehensive assessment of the experience to date with renewable energy projects in developing countries.

Institution-building for the Energy Sector in Developing Countries	**$675**	**A.I.D.**

Project Description: Activities include technical assistance to energy R&D institutions in developing countries, assistance in utilizing relevant energy research capabilities within the United States, and assistance in improving energy planning and decisionmaking structures in developing countries.

Household Fuel Options for Developing Countries	**$685**	**A.I.D.**

Project Description: ORNL has conducted research, technology assessment, and technical assistance related to coal briquette as substitutes for wood charcoal in wood-scarce areas having a coal resource (with market assessments in Haiti and Pakistan), alternative wood sources for charcoal manufacture, and prospects for the implementation of improved cookstoves.

Information Systems Assistance	**$200**	**A.I.D., ORNL**

Project Description: ORNL provides a wide variety of information about energy issues and options in developing countries to A.I.D. offices and missions, other U.S. agencies, multilateral agencies, developing countries, private sector parties, and the research community. ORNL also assists A.I.D. and others in improving systems for information management, project management, and other management priorities.

SOLAR ENERGY RESEARCH INSTITUTE

PROJECT TITLE	TOTAL FUNDING in thousands of dollars (FY 86, 87, 88)	FUNDING SOURCE
United States-Saudi Arabian Joint Program for Cooperation in the Field of Solar Energy (SOLERAS)	**$9,067**	**507 U.S./507 Saudi Arabia**

Project Description: The SOLERAS Program was a unique bilateral, international, cooperative research effort. The intent of SOLERAS was to utilize the technical and financial resources of each country to advance the development of solar energy through cooperative research projects. The Program involved research and applications in most of the major renewable technologies during its nine-year life, and its participants include some of the most accomplished individuals, corporations, universities, and laboratories in solar energy research.

SOLERAS initiated several major research projects: converting solar energy into electricity for everyday use by the inhabitants of several rural villages; testing solar energy as a source for space cooling and water treatment; developing agricultural systems using solar energy to control the entire growing environment; understanding fundamental photovoltaic and solar thermal research; establishing high technology laboratories for advanced solar research at Saudi Arabian universities; and sponsoring basic solar energy science research in universities in the United States.

In addition, SOLERAS contributed to the dissemination of scientific and technical solar information through its sponsorship of technology workshops, short courses, and the publication of technical reports. These provided an important means of informing the scientific research community about the solar energy technologies developed under SOLERAS and other relevant projects throughout the world.

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