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Philip F. Palmedo and Pamela Baldwin

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Prepared for the Office of Energy,
Development Support Bureau,
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PREFACE

In order to accomodate planning needs of the National Security Council and AID the first draft of this report was prepared in a period of less than two weeks and discussed at a meeting at AID on January 17. The discussions at that meeting and the comments and suggestions received as a result of the circulation of draft material have been very helpful in refining the discussion of the paper. We recognize, however, that the depth and refinement of analysis that time limits have allowed us do not do full justice to the issues at hand. Thus we would urge that this report be looked upon as a preliminary and partial step towards a more complete consideration of U.S. energy assistance policy.

Even the long list of contributing authors to this report does not reflect the large number of individuals who made important contributions. In the AID Office of Energy, the immediate sponsor of the work, both Alan Jacobs and Jerome Bosken contributed significantly to the analysis. We are also grateful to Sander Levin and Steven Klein of AID and Morton Gorden of Development Sciences, Inc., for their contributions to our thinking about policy options. Charles Blitzer of the International Development Cooperation Agency (IDCA) provided a number of helpful comments and suggestions as did Henry Kelly of the Solar Energy Research Institute, Charles Bliss of the MITRE Corporation, James Bever of the Institute for Energy Research at Stony Brook, Daniel Dolan

and Erik Eckholm of the State Department, Norman Brown and Robert Ichord of AID's Asia Bureau and Donald Foster of the Department of Energy's Office of International Affairs. We are also indebted to Jane Trigg for her production of the report. The original orientation of the paper was greatly aided by conversations with Edward Fried of the National Security Council.

Despite these intellectual debts, it is important to emphasize that the principal authors of the report take responsibility for the views expressed herein. This is a report from Energy/Development International to AID and does not necessarily reflect AID views or policy.

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EXECUTIVE SUMMARY

I. Introduction

This paper, written in response to a request from the National Security Council, seeks to provide information that will help policy-makers answer the following questions:

(1) What contribution can renewable energy sources - biomass, solar energy, wind, geothermal energy and small-scale hydro-electric power make in meeting future demand for energy in developing nations that would normally be met by petroleum?

(2) What contribution can increased energy efficiency (or energy conservation) play in reducing future developing country oil needs?

(3) What constraints limit the application of renewables and conservation in developing countries (LDC's), and what strategies are needed to overcome them?

(4) What policies and programs might the U.S. government initiate or expand to encourage substitution of renewables and conservation for oil, where appropriate, in developing countries?

While the paper responds specifically to expressed concerns about the balance of future world oil supply and demand, and the U.S. interest in easing future pressures on oil supplies and prices, other U.S. interests related to LDC energy problems are briefly mentioned. These include our foreign policy interest in maintaining political stability and economic progress

in the Third World, and our active policies directed at meeting the basic human needs of the world's poorest people. Assistance to developing countries in the energy area, it is argued, enhance all of these U.S. interests.

II. LDC Energy and Oil Demand

The non-OPEC less developed countries now account for approximately 15 percent of world oil demand and 19 percent of gross world oil imports. Oil demand is growing faster in LDC's than in the rest of the world, despite recent price increases, reflecting the rapid rise in demand that accompanies the early and middle stages of economic development. As a result, many LDC's are experiencing serious balance-of-payments problems and increasingly heavy external debts.

Oil demand in the non-OPEC developing countries is expected to grow from approximately 8 million barrels per day (MBD) currently to 20-25 MBD in 2000. Then, as now, demand will be centered primarily in the more industrialized LDC's; in 1977, eight countries consumed more than 60 percent of all LDC oil use.

III. Potential Contribution of Renewable Technologies

Renewable sources of energy appear to have the technical capability to replace approximately 8-15 percent of LDC oil demand in 2000. Biomass-based fuels appear to offer a prospect of meeting 2.5-5.5 percent of 2000 oil demand. Solar, wind, small-scale hydro and geothermal energy could contribute another 6-10 percent.

The major biomass-based technologies and their estimated potential contributions to substituting for total non-OPEC LDC oil demand in 2000 are:

- ethanol, made primarily from sugar cane and used primarily as a transportation fuel (mixed with gasoline): 1-2 percent of demand.
- methanol, made from wood materials and also used for transportation: 1-2 percent.
- biogas (methane), made by anaerobic digestion of animal and plant wastes in rural areas and used for cooking, lighting and other rural uses: 0-0.5 percent.
- biomass for industry, used either for direct burning or for a charcoal/oil slurry: 1-2 percent of LDC oil demand.

Among the other new technologies, solar offers the greatest potential. Solar applications and their potential for oil substitution for non-OPEC LDC's are as follows:

- solar thermal, i.e., direct uses primarily for water heating in industry and in commercial and residential buildings: 3-4 percent.
- solar electric (central), a still experimental and highly capital-intensive technology involving large land areas of collectors, a tall receiver tower, special boilers and conventional turbogenerators: optimistically, 0-1 percent.

  solar electric (decentralized), photovoltaics for rural areas where the costs of central-station generation and long-distance transmission are prohibitive; used for

irrigation, village street lighting, public buildings and residences: 0.5-1.5 percent.

Other renewable technologies include wind, small-scale hydroelectric power and geothermal. Their potential contributions are as follows:

- wind, used for electrical generation to substitute for oil-fired (primarily diesel) generators and for water pumping: 1-1.5 percent of LDC oil demand.
- small scale hydro, used to electrify villages far from central grids, replacing or avoiding diesel generation: 0.2 -0.4 percent of LDC oil demand.
- geothermal energy, used for industrial process heat, residential-commercial hot water, and electricity generation: 0.5-1 percent of demand.

IV. The Potential for Increased Energy Efficiency

Energy conservation has not received wide consideration as a means of assisting with increasingly expensive Third World oil needs, but our estimates suggest that between 10 and 20 percent of LDC oil demand could be reduced through conservation in the year 2000. Excessively narrow definitions of conservation have often reduced its appeal in both the developing and developed worlds; we define it here to mean primarily an increase in the efficiency with which energy is used, i.e., an increase in the amount of useful work that can be produced with energy unit of energy input. Energy conservation should be seen as a means to accelerate economic growth, industrialization, jobs and income.

Major conservation opportunities for developing countries lie in the industrial, transportation and electricity sectors of the leading oil-consumer nations. In industry, much can be accomplished through very inexpensive "housekeeping" improvements requiring better accounting of energy use patterns, target-setting at the managerial level and implementation of minor but important process changes by technical personnel. Beyond "housekeeping," further opportunities are to be found in retrofitting current equipment and machinery with more efficient systems, in recycling waste products (including waste heat), and, in some cases, in replacing major equipment with more efficient technologies. These measures require progressively larger investments and longer lead-times, as well as better mechanisms for transferring the most efficient technologies and processes from industrialized to developing countries. The cost-effectiveness and policy justification for particular measures must be determined on a plant-by-plant basis. In general, however, it can be said that a phased approach - beginning with housekeeping, and moving on to initially small but progressively larger investments - will yield maximum results in industrial energy conservation over time.

In the transportation sector, long lead times are needed to effect any significant improvements in energy efficiency. The best opportunities in the passenger subsector appear to be in shifts of urban transport modes through development and expansion of mass transit systems. Energy-conscious transportation and land-use planning are prerequisites. In freight transport,

options include gradual replacement of truck fleets with more efficient models, expansion of railroad systems, and careful development of the freight systems of countries in which this sector is growing rapidly.

Greater efficiency in the fast-growing electricity sectors of LDC's can be achieved through use of more efficient equipment in new power plants, larger unit size, better interconnections, improved load factors, choice of small-scale decentralized renewable systems in rural areas, and co-generation of power and steam for industrial uses.

Residential and commercial energy conservation opportunities in LDC's are found primarily in improved design and operation of urban buildings. Building codes to encourage passive solar techniques, and use of life-cycle cost analysis during the design process, appear to hold the greatest promise.

V. Constraints

The above-described potential for replacing about 18-35 percent of LDC oil demand with renewable sources and conservation represents a level of achievement that appears technically feasible and economically justifiable. A number of constraints may, however, preclude realization of these goals in the absence of new policy initiatives. The constraints include:

(1) A lack of institutions and organizations capable of developing and maintaining small-scale decentralized renewable energy systems, particularly in rural areas, and of coordinating such systems with agricultural and rural development activities.

(2) A lack of trained managers, technical experts and technicians to manage the selection, adaption, installation, operation and maintenance of renewable energy technologies.

(3) A lack of emphasis on renewables and conservation within the major lending institutions which have heretofore focused their energy-related financing primarily on rural electrification, large hydro and fossil fuel development.

(4) Inadequacy of existing mechanisms for the transfer and adaptation of technologies from industrialized to developing nations, particularly in light of changing (and sometimes apparently conflicting) aims and interests of both the producers and the consumers of such technologies.

(5) Policy confusion resulting from uncertainties in the outlook for conventional fuels - uncertainty, for example, about the future availability and price of oil, coal production and export potential in the nations with large coal resources, and the effect of energy problems on economic growth and balance-of-payments in all nations.

(6) Current orientation of energy RD & D programs in industrialized countries toward the large-scale, capital-intensive technologies that are more appropriate to industrialized than to less developed countries, combined with a serious lack of R & D programs within LDC's.

(7) Cautious attitudes toward both renewables and conservation on the part of LDC governmental and private sector policy-makers, partly due to a perception that these approaches have not been accorded high priority in the energy policies of nations urging them on LDC's, and partly out of concern that renewable and conservation strategies could simply replace oil-

dependence with technology-dependence.

(8) A shortage of practical experience and information about actual performance of renewable and conservation technologies in the field, in order to clarify issues that must be faced in major investment decisions.

VI. Current Programs

In surveying current activities in renewables and conservation for LDC's, we have focused primarily on the programs and policies of U.S. government agencies, particularly the Agency for International Development (AID) and the Department of Energy (DOE). We also mention briefly the efforts undertaken by the United Nations system, the World Bank Group, and the individual member nations of the Organization for Economic Cooperation and Development (OECD).

Quantifying specific expenditures r renewable technologies and conservation has proven difficult, since such outlays are usually incorporated within larger, multi-purpose and multi-technology projects. Nonetheless, we estimate that AID has, between FY 1978 and FY 1980, spent roughly $20 million for assistance related to biomass-based fuels (including $12 million for fuelwood), $20 million for all other renewable technologies (solar, wind, mini-hydro and geothermal), and $50 million on programs that offer indirect support through energy assessments, training, institutional development, etc. Only about $1 million in AID funds has gone toward conservation of commercial fuels, and about $2 million (part of the $12 million for fuelwood

mentioned above) toward conservation of traditional fuels through more efficient cookstoves and charcoal conversation processes.

DOE has expended approximately $8 million in FY 1979 and FY 1980 on its primary LDC-related activity, the country energy assessments.

VII. Conclusions

If the estimated savings projected in this paper are achieved, world oil demand could be reduced by 4 - 9 million barrels per day in 2000. Due to the current uneven pattern of distribution in LDC oil consumption, this saving that might result from vigorous renewable and conservation strategies, will also be heavily concentrated in a relatively few countries. The Third World's leading oil consumers are, for the most part, also the leaders in wealth and industrialization. (India, despite a large industrial sector, is a notable exception.) A strategy concerned primarily with world oil supply and demand should, therefore, be aimed primarily at the most advanced LDC's.

On the other hand, there is reason to focus also on the large number of primarily adgriculural countries that - despite very small aggregate oil demand (less than 2 percent) - are experiencing the most severe national problems with import dependence, balance-of-payments deficits and heavy external debts.

Acute as they are now, these problems are not likely to be limited to the short term, and solutions will also require a long-range view. Renewable energy technologies cannot

realistically be expected to make a dent in oil demand in the next few years, but neither can programs to accelerate fossil fuel development. Increased energy efficiency, however, does offer at least modest short-term benefits. Bearing in mind the need for all nations to prepare for an eventual "post-petroleum era," we conclude that programs to encourage energy efficiency improvements and substitution of renewables for oil should be part of any long-range energy assistance strategy for LDC's.

Current programs appear not to reflect the relative potentials of these strategies. The near-total lack of activity in the conservation area is particularly striking, in light of our analysis of its potential for reducing LDC oil demand. We conclude that the U.S. government should seriously evaluate the need for increased emphasis on programs to improve the efficiency of energy use in all sectors of LDC's.

This analysis also suggests that non-technical constraints upon the implementation of renewable and conservation strategies are likely to be more limiting (and more difficult to overcome) than the well-known technical barriers. These non-technical constraints include -- but are not limited to -- LDC governmental attitudes, lack of market incentives caused by government policies (such as subsidies on certain fuels), absence of foreign policy considerations (particularly consciousness of LDC needs) in U.S. technology development programs, and inadequacy of financing mechanisms.

VIII. Policy and Program Initiatives

Initiatives suggested by the analysis fall into three major categories: technical, economic/financial, and institutional.

Technical efforts should be directed at an acceleration of RD & D - including extensive field-testing - of the most promising renewable and conservation technologies for application in LDC's. Such efforts might include review and modification of existing Department of Energy RD & D programs, carried out jointly with LDC energy experts; creation of specific LDC energy technology line items in the DOE budget; and establishment of an advisory body to review DOE's programs and identify the activities with greatest potential LDC relevance and utility. For most renewable technologies, the major requirements appear to be in the development and demonstration phases, rather than in basic research.

Economic and financial measures should be designed to create a more favorable investment climate for renewable and conservation technologies both in the U.S. and in developing countries. Specific incentives might include low-interest loans, loan guarantees, subsidies, insurance, modification of lenders' and donors' loan or grant criteria, and aggregation of numerous small-scale financing requests into packages of manageable size for lending institutions.

Institutional measures would include, among other options, development of better information systems; creation of national organizations to do energy planning, assessment, training and policy-making in LDC's; expansion of all training efforts; and improvement and expansion of technology transfer programs.

Initiatives that could contribute to remedies for all three constraint categories -- technical, financial and institutional -- might include:

-- the provision of technical expertise to assist LDC's in evaluating conservation opportunities and in producing energy conservation plans that are sufficiently detailed to justify positive investment decisions by public and private financial institutions; and

-- the active support of the U.S. government for preparations now getting underway for the United Nations Conference on New and Renewable Energy Sources, in order to assist in the evolution of positive views toward renewables in LDC's.

Two broader policy needs emerge strongly from the analysis:

-- The definition of a U.S. energy assistance policy based on the full set of U.S. concerns and interests in developing countries - and not only the partial set now reflected in assistance programs.

-- The definition of a major new international effort aimed at improving the effectiveness of energy use in

developing countries in support of their economic and social development goals.

I. INTRODUCTION

A. BACKGROUND

This report was prepared as a contribution to the Interagency Task Force for Accelerated Energy Production in the Developing Countries. The Task Force is preparing a report for the National Security Council to determine whether there are actions which can be taken by the United States to increase energy production in developing countries. The report takes as its primary concern the world oil supply-demand balance and will address a number of issues such as ways to improve information on resource endowments, the status of exploration and development for hydrocarbons, and the potential role of coal as a substitute for oil. In all cases, a major policy issue will be actions that could be taken by the United States, bilaterally or through international organizations to accelerate oil production or substitution.

Two additional subjects are of major interest in this context: the potential for meeting future energy demands in LDC's by renewable resources such as solar energy and biomass rather than by oil; and the potential for increasing the efficiency with which oil is used in order to reduce the rate at which the demand for oil will grow in the future. These two issues are the subject of this paper. For each we must ask three types of questions: what is the technical potential for affecting future

oil demand; what are the constraints and conditions under which programs to effect such strategies will succeed in individual countries; and what new programs or policies can the United States pursue to forward those strategies? These are large and complex questions which could be addressed only partially in the two weeks that were available for the analysis, despite the large number of individuals who contributed to the substance of the paper. Given the nature of the problem posed (and the time available to address it) we have chosen to focus in this report on the broader institutional and policy issues involved, rather than technical-economic details which are addressed in a number of other documents.*

B. THE OIL PROBLEM AND BROADER DEVELOPMENT ASSISTANCE ISSUES

It is important to distinguish the questions addressed in this paper from broader questions of development assistance policy. Here we restrict our attention to the issue of reducing future oil demand by the increased use of renewable resources and by making national energy systems more efficient in their use of oil.

The goal of reducing oil demand is itself complex, as we discuss below, but is only one criterion out of several that should be considered in arriving at a balanced energy assistance

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*/ References 1-17 constitute a basic bibliography in this area.

program. Such a program should be based on two types of consideration: 1) the character of the energy problems that will be confronting the individual developing countries over the next decades, along with possible solutions to those problems and 2) the set of U.S. interests that are at stake in the developing world. In addition to problems related to levels of imported oil, the LDC's have other critical energy concerns, particularly related to depleting supplies of non-commercial fuels such as wood and dung which have been their traditional energy sources. At the same time, there are a number of U.S. policy concerns that should come into play in determining assistance policy in addition to the world supply of oil. Prominent among these is the national interest in political stability in key regions and countries and the social and political destabilizing effects of rapid energy price increases and shortages. As another example, U.S. assistance has a long-standing concern with the basic human needs of rural populations. Problems of energy supply are now critical in many rural areas and energy programs are of very high priority within the context of assistance for basic human needs. The fact that many such programs may not have major implications for world oil supply does not diminish their basic importance.

Even if one focuses only on oil consumption in the developing countries, there are two basic issues to be addressed from the perspective of U.S. assistance policy. First, the developing countries represent an increasingly large share of the world's

oil demand. Now accounting for about 16 percent of world oil consumption, or 19 percent of world gross imports of oil, the third world continues to increase its oil consumption at a rate greater than the rest of the world. This despite the price increases of 1973-74 and 1979 and the drastic effects of those increases on the balance of payments of many countries. This results from the crucial role that oil now plays in the economic growth of countries in early and intermediate stages of development. Various projections anticipate oil demand in the non-OPEC developing countries attaining 20-25 million barrels per day by the year 2000, or 20-25 percent of world demand.[19/] Whether such growth rates can be sustained is problematical at best but the fact remains that if the developing countries are to achieve economic growth rates approaching what they expect, and what is required to close the gap between the rich and poor nations of the world, their consumption of oil will become a more and more significant fraction of the world's total.

The second important issue regarding oil in developing countries is the extremely large burden that oil imports now place on countries' balance of payments situations. Many oil importing developing countries are now forced to devote a substantial fraction of their export earnings to the purchase of oil. This has contributed substantially to the doubling of the external debt of those countries in the last 5 years (1973-78). The current account deficit of the oil importing developing

countries is expected to increase from a level of $32 billion in 1978 to over $50 billion in 1980.[2/] Thus, for many developing countries as world oil prices continue to increase, reducing levels of oil consumption has become an absolute necessity if they are to remain economically stable. The oil issue in U.S. energy assistance must also focus on this concern at the country level.

C. STRUCTURE OF THE PAPER

Before addressing the role of renewable energy sources and conservation in reducing future oil demand, one must understand the structure of that demand at a national level. That is the subject of the next section in the paper. There follows a section in which estimates are made of the rate at which renewable resource technologies can meet future demand which otherwise would be met by oil. A corresponding section follows on the potential for reducing future LDC oil demand by making more efficient use of fuels. In the next section we discuss various types of barriers and constraints that can limit the rate at which renewable resource or conservation strategies can be implemented.

The following section deals with development and assistance programs in both the renewable resource and conservation areas by the U.S., other national assistance agencies and international bodies. The next section draws a number of conclusions from the analysis regarding the implications of alternative assistance

strategies. This is followed by a discussion of possible U.S. policy initiatives both in terms of programmatic content and institutional mechanisms.

II. CHARACTERISTICS OF LDC ENERGY AND OIL DEMAND

In this section we briefly summarize those aspects of energy demand in developing countries which are pertinent to the policy issues addressed in this paper. Since oil is our principal concern, the discussion will focus on the modern sector. However, we will also comment on the interaction between current traditional energy use and future oil use. The discussion will draw on energy balances for selected countries presented in Appendix A.

A. COMMERCIAL ENERGY

The structure of current consumption and future demand for energy in developing countries depends strongly on their overall economic structure and related social-demographic patterns of settlements. It is analytically useful to divide the developing countries into five relatively homogeneous groups based on the various stages and patterns of development implied by such indicators as per capita income, degree of industrialization and urbanization as well as by characteristic economic and resource structures which determine their developmental and energy choices[13/].

Table II.1 shows a division of 86 selected developing countries into these 5 groups classified as follows:

I) Industrialized: In this group, the industrial sector accounts for the largest share of GDP and there is relatively more "modern" industry and less traditional handicraft production compared to other LDC's.

II) Oil exporters: Countries in this group have a set of common choices confronting them; the rate of development and use of their resources and the pattern of investment of this export earnings. Most of these countries face sizeable short-term debt service (e.g. Peru) and/or domestic public spending needs (Indonesia, although an OPEC country, would fall into this category).

III) "Balanced" Growth Economies are characterized by industrial structure which is relatively developed but not dominant in its share of GDP. The agricultural sector is very important in terms of employment of the total labor force as well as in the economy. These countries also have, generally, a diversified and fairly substantial resource base but are not yet relatively speaking, committed to any particular development course.

IV) Primary Exporters are those in which the economy is basically dependent on exports of a few minerals which also account for the bulk of exports. Their commercial energy consumption is low and is generally linked to primary mineral extraction and transport.

V) In the Agricultural Economies, the agricultural sector dominates in the share of GDP. This group can be further

TABLE II.1

Categories of Developing Countries

I. Industrialized

Argentina
Brazil
Chile
*South Korea
Singapore
Spain
Taiwan
Uruguay
Yugoslavia

II. Oil Exporters

Angola
Bolivia
Congo
*Egypt
*(Indonesia)
Malaysia
Mexico
Oman
*Peru
Syrian Arab Republic
Trinidad and Tobago
Tunisia

III. Balanced Growth Economics

Colombia
Greece
India
*Pakistan
Panama
Philippines
*Turkey

IV. Primary Exporters

Botswana
Guinea
Guyana
*Jamaica
Liberia
Mauritania
Morocco
Sierra Leone
Surinam
Togo
Zaire
Zambia

V-a. Agricultural Exporters

Costa Rica
*Dominican Republic
Gambia
Guatemala
Honduras
Ivory Coast
Senegal
Sri-Lanka
*Thailand

V-b. Other Agricultural

Afghanistan
Bangladesh
Benin
Burma
Burundi
Cameroon
Central African Republic
Chad
Cyprus
El Salvador
Eq. Guinea
Ethiopia
Fiji
Ghana
Haiti
Jordan
Kenya
Lebanon
Lesotho
Madagascar
Malawi
Mail
Mauritius
Mozambique
Nepal
Nicaragua
Niger
Papua N. Guinea
Paraguay
Rwanda
Somalia
Swaziland
*Sudan
Tanzania
Uganda
Upper Volta
Yemem A. Rep.

* Demand analysis given in Appendix A.

sub-divided into Agricultural Exporters (east African countries, most Central American and Caribbean countries and some in Asia and South America) dependent on exports of one or two agricultural commodities and other agricultural (most African) countries, largely characterized by subsistence/nomadic farming.

From the energy use point of view, the utility of this classification lies in the relative homogeneity of energy consumption patterns found in each group. For example, in category I, the industrial sector dependent on commercial fuels is dominant in energy use while at the other extreme, in category V, subsistence energy use in rural households (largely food preparation) making use of non-commercial fuels such as firewood is dominant. Table II summarizes the commercial energy, petroleum, and non-commercial energy consumption in each of these groups. Commercial energy use/capita rises almost ten-fold and petroleum consumption/capita about seven-fold between categories V and I. To a first approximation, the growth in per capita commercial energy consumption tracks fairly closely the rise in GNP/capita. However, another effect is also fairly striking: petroleum increases as a fraction of total energy from category I to V, suggesting the extreme dependence of the poorer agricultural countries on petroleum products for their entire commercial energy supply. (The figures for category III are distorted by the inclusion of India which is a heavy user of coal). This has important implications for energy assistance focused on oil consumption.

TABLE II.2

DEVELOPING COUNTRY GROUP CHARACTERISTICS
(Primarily 1975 Data)

Group	No. of Countries	Population (millions)	GNP/cap. ($/cap.)	Energy Cons. MBDOE[a]	Petroleum/ Total Comm.[c]	Fractional Oil Consumption by Sector Industry[b]	Transportation[b]
I Industrialized	9	262	1120	5.06	0.663	0.35	0.24
II Oil Exporters	10	134	740	2.13	0.688	0.25	0.45
III Balanced Growth	8	784	221	7.19	0.408	0.25	0.45
IV Primary Exporters	13	61	313	0.51	0.731	0.6	0.3
V Agricultural	45	398	162	2.68	0.897	0.2	.3 - .5
Total or (Average)	85	1640	(396)	17.57	(0.60)	(.3)	(.4)

Notes: a) Million barrels per day oil equivalent
1 MBDOE = 2.24×10^{18} joules per year

$= 2.12 \times 10^{15}$ Btu per year

b) There is large variability in these numbers between countries depending on resources and industrial structure.

c) The ratio of petroleum consumption to total commercial energy consumption.

Source: "Energy Needs, Uses and Resources in Developing Countries"[13/] and E/DI estimates.

In 1977, eight countries accounted for over 60% of total oil consumption among non-OPEC LDC's, as shown in Table II.3. The table also demonstrates the high import-dependence of many of these nations.

It is interesting to note the differences between the energy economic growth patterns of developing and developed countries over the last few years. In general the developing countries have exhibited somewhat higher economic growth, and considerably higher energy growth than the developed countries. Although energy consumption per dollar of GNP has fallen steadily over the last several years for the industrialized countries, (at over 1 percent per year) it has increased steadily in the developing countries. Even since 1973 the ratio has increased at about 1 percent per year.

There are a number of projections of future LDC energy and oil demand and they span a very large range of consumption in 2000.[18/] The major uncertainties in these projections are economic growth rates, the future relationships between oil consumption and economic growth, future world oil prices and the effects of price on consumption. The variability of these assumptions have led to projections as low as 15 million barrels per day in 2000 [13/] to ones as high as 23 million barrels a day in 1990. The latter estimate, made as a contribution to a World Bank study [19/] implies a consumption in 2000 of over 40 million barrels per day, but is based on no real oil price increases beyond 1978 - already an invalid assumption. As representative of the range of plausible oil demand projections for the non-OPEC LDC's in 2000 we choose 20-25 million barrels per day for the purposes of this report.

TABLE II. 3

DAILY OIL CONSUMPTION (1977)
AND ENERGY IMPORTS AS % OF EXPORT EARNINGS (1976)
FOR THE 8 LEADING OIL CONSUMERS
AMONG NON-OPEC LDCs

Country	Daily Oil Consumption (MBD)	Energy Imports/ Export Earnings (%)
Brazil	1.008	43
Spain	.932	59
Mexico	.841	10
India	.548	26
Argentina	.466	14
Korea	.422	23
Yugoslavia	.288	22
Taiwan	.280	NA
Philippines	.219	NA

Source: a) Daily oil consumption: U.S. Department of Energy, International Petroleum Annual, 1977

b) Energy Imports as % of Export Earnings: World Development Report, 1979 (Reference 1)

This range corresponds to GDP growth rates of 5-6 percent per year, an income elasticity of 1.2-1.4, a price elasticity of -0.3-0.4, and oil prices reaching $50-$70 per barrel (in 1978 $) by 2000. This demand will then represent 20-30 percent of total world oil demand at that time.

Differentially, it is to be expected that the consumption in the poorer countries, which now represent a small fraction of total LDC demand, will also grow the slowest. The share of total LDC petroleum consumed by agricultural economies (10 percent in 1975) will decrease to about 7 percent in 2000[13/].

Individual Countries Analysis

From the five broad categories we have selected 10 countries for detailed investigation into the structure of energy consumption by economic sector. The choice of countries by group are shown in Table II.4.

Group	Sample Countries
Industrialized	South Korea
Oil Exporter	Peru, Egypt
Balanced Growth	India, Pakistan, Turkey
Primary Exporter	Jamaica
Agricultural	Sudan, Dominican Republic, Thailand

Although these countries have a widely varying set of natural resource endowments (notably natural gas in Pakistan, coal in S. Korea, India and Turkey, hydropower in Peru and Egypt) nevertheless certain patterns and trends appear to emerge from a detailed consideration of energy and petroleum use in industry, agriculture,

transportation, residential-commercial and the electric generation sectors. The details of the sectoral breakdown of energy consumption in the 10 countries selected is given in Appendix A.

Transportation is a very important oil consuming sector, ranging from a low of 25 percent of oil consumption in Korea to a high of 51 percent in Sudan and Pakistan. A large fraction of this arises from essential economic activity such as transport of commodities which is not easily susceptible to discretionary cutbacks without infringing seriously on basic services. Oil use in industry varies from a high of 35 percent of oil consumption in Korea to a low of 13 percent in the Sudan. A substantial amount of oil consumption goes to electric generation. In terms of energy consumed in the electricity generation sector, oil accounts for as high a fraction as 90 percent in the Dominican Republic to 30 percent in Korea. Substitution for this use opens much wider possibilities of technological alternatives.

B. TRADITIONAL FUELS

Roughly 80 percent of the people in the third world--or half of the world's population--depend on the traditional fuels of wood, animal dung and crop residues[21/]. In countries at very early stages of development the traditional fuels can constitute 80-90 percent of national energy consumption. That percentage tends to decrease as income increases and countries become "modernized" and dependent on the more convenient and flexible fossil fuels. Table II. 5 summarizes the contribution of traditional fuels to national energy use in the countries analyzed in Appendix A; the trend with income is apparent.

TABLE II.5

TRADITIONAL ENERGY AS A PERCENT OF TOTAL CONSUMPTION

Country	Traditional Ratio	GNP/Capita[a] (1974)
Sudan	.85	230
Indonesia	.71	224
Thailand	.53	310
Pakistan	.46	130
India	.46	140
Egypt	.33	280
Dominican Republic	.32	650
Peru	.32	740
Turkey	.26	750
Korea	.11	390

a/ U.S. $

Under the pressure of population increases the ancient patterns of traditional fuel use are undergoing new stresses. In many areas of the developing world forests are being destroyed through lumbering, land clearing for agriculture and scavenging for firewood. It is estimated that tropical forests have been reduced from their natural extent by more than 40 percent [22/]. The difficulties of finding firewood lead rural people to turn increasingly to dung and crop residue for fuel, with attendent damage to agricultural productivity.

Petroleum based fuels have always constituted the natural replacement for traditional fuels as development progresses and as the traditional fuels become scarce, or commercialized and expensive. But even as the pressure towards oil based fuels is increasing, their cost rises and they become less accessible to the rural and urban poor. For example, the World Bank calculates that in the absence of a massive tree-planting campaign in Nepal, the additional dung that will be burned by the year 2000 will reduce food grain output there by one million tons.

The oil price jumps of 1973, however, brought the spread of fossil fuels in households to an abrupt halt in many countries. Residents of some more isolated areas have in fact been forced backward in history by the scarcity and high prices of kerosene, which have caused them to shift back to fuelwood regardless of the resulting ecological stresses and work burdens.

This situation has created a new tension between traditional and commercial fuels. This tension can be resolved by "simply" reducing the consumption of traditional fuels but in much of the developing world that consumption level is already near or below the levels required for basic subsistence. It can also be resolved by subsidizing the cost of commercial fuels, for example kerosene, to those most seriously affected. But that solution is incompatible with the extreme balance of payments problems confronting the oil importing LDCs and the desirability, from an efficiency point of view, of realistic internal pricing. It is a choice between Scylla and Charybdis. In the longer term various strategies (and assistance programs) can help resolve this tension but there is no acceptable solution in the short term and no common outcome that can be foreseen for all countries.

The implications of this situation for liquid fuel demands in the LDCs is discussed in Section III. B.

III. RENEWABLE RESOURCE POTENTIAL

A. INTRODUCTION AND SUMMARY

The intent of this section is to arrive at estimates of the degree to which various renewable energy resources can meet future energy demand in the non-OPEC developing countries. More specifically we are interested in the degree to which these resources can be used either to replace oil in its current use or to meet future energy demands which otherwise would be met by oil.

This analysis is extremely difficult to perform with any accuracy or degree of confidence given the current lack of practical commercial experience with the resources and technologies in question. Despite the widespread enthusiasm for renewable resources (perhaps because of it), there is a surprising lack of analyses of the potential impact of renewable technologies, even at the country level, not to mention the global scale. The scope of this analysis does not permit extensive new analyses. Fortunately, however, to address the central policy questions of concern we do not require a highly detailed or disaggregated analysis. As a first step we aim only at an order of magnitude of the potential of renewable resources. This should be kept in mind lest the reader be stunned by the somewhat heroic assumptions that we will be forced to make in our analysis.

Our general approach is as follows. For each of the major types of technologies that may be available to use renewable energy sources, we first characterize the state of the technology including its applicability to specific demand sectors in which oil is used, and its economic competitiveness. Since technical descriptions of the technologies are readily available elsewhere,[23/] we describe only those aspects of the technologies directly pertinent to our argument. We then analyze the rate at which the technology can enter the energy system of a country which is well endowed with the resource in question. This gives us an estimate of the degree to which the technology can substitute for oil at the country level. We then make an estimate of the degree to which the specific countries considered in the analysis are typical, or, more precisely, what fraction of oil consumption in non-OPEC LDC's is in countries or regions of countries with comparable potential for implementation of the resource. This fraction we term the global scale factor. The product of the fraction of oil substituted nationally times the global scale factor then gives us a (very approximate) number for the potential role of the technology in substituting for oil in the LDC's.

It is important to recognize that we are dealing in this chapter with rates of introduction of technologies that are technically feasible, considering economic competitiveness. We do not consider in this chapter limitations which may be imposed by financial or institutional constraints. These are discussed in a subsequent chapter.

We have taken the year 2000 as the reference year for our analysis. A preliminary analysis indicated that any earlier period would not show significant impacts. Longer term considerations are discussed in the conclusions section.

Summary

Table III.1 summarizes the results of the analysis. The details of this table will be comprehensible only through the detailed discussion in the remainder of the chapter but the basic significance of the numbers can be summarized as follows. Each renewable energy technology applies to a specific oil use; for example, central station electricity generation or steam generation in industry. The first column in the table indicates the amount of oil typically used for the specific purpose targeted by the resource/technology considered. The second column indicates the fraction of oil for that purpose that could be replaced by the new technology (the market penetration). The next column is the fraction of national oil saved (the product of the previous two numbers). The global scale factor, discussed above,is shown next and, finally, the product of the last two numbers which gives the fraction of total projected LDC oil demand that can be replaced by 2000 by the new resource/technology.

For some uses there is potential competition between the technologies considered. On the other hand, the countries where the different technologies apply are generally quite different and the assumed rates of implementation are generally not very high. Thus, as a

TABLE III.1

SUMMARY OF RENEWABLE RESOURCE POTENTIAL

Resource/Technology	Fraction of National Oil Used for Targeted Purpose (Percent)	Market Penetration in 2000 (Percent	National Oil Saved (Percent)	Global Scale Factor	Demand Reduction (Percent)
Solar Thermal	12	30-50	4-6	0.7	3-4
Solar Electric - Central	20	4	0.5 - 1.2	0.7	0-1
Solar Electric - Decentralized	3	50	1-2	0.7	0.5-1.5
Wind	20	30	5-7	0.2	1-1.5
Small Scale Hydro	10 c/	5	0.5-1	0.4	0.2-0.4
Geothermal	15 d/	25	3-4	0.2	0 .5-1
Biomass - Liquid Fuels	40	20-30	8-12	0.25 a/	1.5-3
Biomass - Biogas	5	10-20	0.5-1	0.5	0-0.5
Biomass - Industry	40	15-30	6-12	0.2	1-2 b/
Other e/					0-0.5

a/ These countries include those that have significant sugar production and those in the significant wood resources. The overlap between these categories reduces the total impact calculated in the text.

b/ Roughly half of this comes from charcoal-oil mixtures and one half from direct biomass use.

c/ Small-scale hydroelectricity is assumed to substitute in part for large-scale hydro for electricity.

d/ Oil use in geothermally endowed countries has been reduced from 20 percent used for other technologies due to presence of hydro resources.

e/ Includes OTEC, wave power, tidal power.

first order we can sum the various contributions in the table. This leads to a total potential impact of renewable technologies of from 8 - 15 percent of projected LDC oil demand in 2000. This represents from 1.5 to 4 million barrels of oil per day in 2000. It is interesting to note that biomass technologies contribute about one third of the total. The other major potential appears to be in solar thermal applications.

B. BIOMASS

As discussed above, biomass, and particularily wood, is now the major inanimate energy source for much of the population of the developing world. Although in this section we are primarily interested the degree to which the use of biomass can be increased in order to meet demands projected to be served by oil, it is of interest to look first at the other side of the coin: the amount of oil that would be required to substitute for existing wood use.

As an example, consider the amount of wood, dung and crop waste now used for rural cooking. If all of the 2.1 billion people now estimated to use these fuels for cooking were to switch to kerosene (at an approximate consumption of 75 liters per capita per year) oil consumption would increase by 2.7 million barrels per day, roughly equal to current total LDC oil imports. Although such a switch is completely unrealistic, some portion, corresponding to the more affluent urban woodfuel users for example, is a potential market which can be measured in the hundreds of thousands of barrels per day. This serves to emphasize the importance of the wood to kerosene tension discussed earlier and programs which address it.

Liquid Fuels From Biomass

Transportation accounts for roughly 40 percent of the oil used in developing countries. It is also the use which is the most difficult to substitute with non liquid fuels such as coal or electricity. Thus there is a high priority in finding a renewable source of liquid fuels useable in the transportation sector. Here we consider two: ethanol produced from the fermentation of sugars and methanol produced from woody material. Although there is a large number of crops and combinations of fuels and technologies, we will consider sugar ethanol and wood methanol as reference technologies for our analysis. This does not affect our argument appreciably.

Ethanol is currently produced by fermentation of sugars and starches. The technology - at least the basic technology - is well established and relatively widespread. Further developmental research is under way.[24/] The most prominent program is that in Brazil where the first goal - a 20:80 mixture of ethanol in gasoline on a national basis is close to being achieved. The Braziliam target of alcohol production was recently raised to 160,000 barrels per day of oil equivalent (BDOE) (allowing 1 barrel of ethanol to be equivalent to 1.2 bbls. of crude oil), compared to a current output of around 40,000 bbls/day. This increase of 20-25,000 BDOE per year will require an investment in new distillery plant and equipment of half a billion dollars per year.

A key problem with ethanol from sugarcane (or corn) is that the raw material tends to be produced on valuable agricultural land and is thus competitive with food crops. This problem becomes more important as population increases and greater food demand per capita accompanies economic growth.

Methanol can be produced from woody material through thermo-chemical conversion techniques which break down the complex organic molecules in the original material to products with simpler structures. One promising pathway is to produce synthesis gas, a mixture of carbon monoxide and hydrogen, through pyrolysis of biomass in a low-oxygen atmosphere. Although this process has not been proved at a commercial scale, synthesis gas is a conventional raw material for manufacturing liquid methanol by a well established technology.[25/]

The comparison between the characteristics of ethanol from sugar cane and methanol from wood is complex. First, economic methanol plants are expected to be substantially larger than ethanol plants.

Second, the thermochemical conversion of biomass to methanol is apt to be more capital intensive, larger scale, and operationally more demanding than is that for ethanol plants. Ethanol plants are normally $5-25 million and 500-2500 b/d, while thermo-

chemical methanol plants are likely to be $100-350 million and 5-15,000 b/d. It should also be recognized that methanol is both toxic and has corrossive properties which could lead to higher costs in its use.

Costs of ethanol and methanol from biomass are subject to a number of local conditions and are still somewhat speculative, but they range from $14-20 per billion joules (GJ) for sugar based ethanol and $8-10 per GJ for wood-based methanol. These costs can be compared with the current price of gasoline of $15 per GJ ($2.00 per gallon), or crude oil costs (at $26 per barrel) of $4.5 per GJ.

The Production Potential: Ethanol

The competition with agricultural production is a critical element in estimating the possible production of ethanol from sugar cane or related crops. In terms of economic competetiveness with oil, we can say that at oil prices (current or anticipated)of about $40 per barrel, suitably adjusted to reflect shadow costs, ethanol production from sugar cane will be seen to be attractive, as it has been in Brazil. Brazil serves as the example, of course, but, because of its current head start we estimate that a 20-30 percent replacement of gasoline by 2000 would be a resonable target for sugar producing countries. (Note: Brazil is close to 20% now and plans to produce about 1/3 of its automobiles in the 80's to operate on pure ethanol). For such countries (in which transportation accounts for about 40 percent of oil consumption) this can replace about 8-12 percent of oil requirements.

To guage a global scale factor, it can be noted that Brazil produces about 3 percent of the world's sucrose. Other major producers are:

Cuba	India	Egypt
Mexico	Taiwan	Dominican Republic
China	Argentina	Philippines
Peru	Indonesia	Columbia
Iran	Pakistan	

While sugar beets account for some part of this production, even in Asia that fraction is only around 12 percent.[26/] We estimate that from 10-15 percent of the regions of the world have conditions similar to those in Brazil. Thus we estimate that ethanol from sugar has the potential contribution of 1-2 percent of future LDC oil requirements.

Production Potential: Methanol

To estimate the potential amount of liquid fuels that could be produced from wood, we have followed the analysis of Reference 27. That study analyzed the wood (and other) resources of six countries: Peru, Thailand, Indonesia, India, the Sudan and Tanzania, and estimated the amounts that could potentially be made available on a sustainable basis to produce methanol after subtracting out current and projected uses of wood for other purposes. A country-by-country analysis resulted in an estimate that 3-4 percent of the annual wood production could be devoted to methanol production. In the case of Indonesia and Peru the estimate was lower than the average due to the inaccessibility of the resource. This ultimate potential corresponded to roughly 10-25 percent of national oil demand. In a separate study, it has been estimated that, in Central America, if 10 percent of the annual renewable growth of the forests of the region were devoted to methanol production, approximately 30 percent of the total petroleum demand projected for the year 2000 could be satisfied.[45/] If we assume that given the state of methanol

technology only 5-10 percent of national oil demand in favorable countries can be met by wood-based methanol, and that 15-20 percent of the developing world has this kind of resource situation, then the resulting potential contribution to LDC oil demand ranges from 1-2 percent, comparable to that of sugar based ethanol. In many tropical countries, significant and sustainable methanol production is contingent on major improvements in forest management.

Biogas Systems

Biogas systems are the junior versions of ethanol or methanol plants. They are simple tanks in which mixtures of organic materials are broken down in the absence of oxygen to produce a mixture of methane and other gases. This process has been used in urban waste disposal for many decades, and its utilization for producing energy at the village or individual household level is being investigated in many countries. China and India are two countries where the technology has, perhaps, been most extensively implemented in rural areas.[28/] Animal wastes are the most widely used input materials in the digestors currently operating although crop residues or a mixture of crop residues and animal wastes can also be utilized. One great advantage of anaerobic digestion is that the left-over slurry after the digestion process generally preserves the nutrient values of the input feed and can be used as a good organic fertilizer. The gas produced can be used for cooking and lighting and even purposes such as electricity generation if the unit is built at a village, rather than a farm scale.

The interest in biogas systems stems from the basic simplicity of the technology, its applicability to decentralized areas and the low cost of the energy produced. A community size plant in India, for example is estimated to produce methane at $2-4 per billion joules compared to $8-15 billion joules for biomass-based ethanol or methanol.[29/]

It is difficult to assess the degree to which biogas systems can substitute for oil in rural applications in part because of the competing uses of the resources consumed and in part because of the uncertainty of future oil use in these areas. Experience in India and China suggest that, for well endowed countries, (particularly where agricultural wastes are not used efficiently) such systems may replace 10-20 percent of rural oil demand or up to 1 percent of national oil requirements.

Biomass For Industrial Fuels

There are many small industries in rural areas of developing countries which now use wood and agricultural and processing wastes of various sorts for energy supply. Their total energy use is usually small but warrent some attention if only to prevent conversion (in the historical pattern) to liquid fuels. There are other areas, however, where there may be a significant potential for the use of biofuels in industry. We take as an example the use of charcoal in charcoal-oil slurries.

Such slurries have already been used under specialized circumstances to stretch oil supplies. In 1979 in Brazil, for example, fuel oil allocations for industry were cut back by the government, and it appears that a variety of industries in Minas Gerais took advantage of the piles of charcoal fines lying

unused by smelters and slurried them with their remaining fuel oil. There are indications that the charcoal program in Minas Gerais is being expanded in scope to profit from the implications of this new experience. Even more than is the case with coal-oil slurries in this country, charcoal-oil slurries can be used with a minimum of modifications to the fire box of an oil-fired boiler. This fact plus the relative simplicity of the conversion process makes the strategy one of considerable interest in a number of countries. Compared to ethanol - the most widely discussed route for biomass substitution for oil in the modern sector - the strategy seems far closer to economic competitiveness, though this fact is obscured by the policies of governments which frequently tax gasoline heavily and subsidize fuel oil.

Charcoal is 1/3 to 1/2 as expensive as ethanol per GJ of oil substituted and may therefore be of interest to a wider range of countries than alcohol. While the impact is still likely to be modest overall it can probably exceed that for substitution in the transport sector. Really broad utilization of charcoal in industry is likely to require an improved solution to the problem of utilizing the pyroligneous tars.

If we assume that 15 percent of oil use (industry and oil used in some thermal power stations) is susceptible to mixtures of 20-40 percent charcoal, then countries well endowed with wood resources could replace 3-6 percent of their oil in this way. As above, we assume 15-20 percent of the developing world to have such resources which gives a figure of .5-1 percent for the total LDC substitution potential.

Where biomass resources are nearby small industry may find direct combustion of biomass to be the cheapest use. Industrial use will be limited by the special design requirements, and greater expense of a boiler for wood and transport costs to sites close to

concentrations of biomass. This will probably limit application to an expansion of biomass use in industries where it is already used. We have very little idea how much oil is consumed in such industries today, but based on the reasoning as given above, we would judge an overall target for this use to be 0.5 - 1 percent of total LDC oil use.

C. SOLAR ENERGY

The developing nations lie for the most part near the equatorial regions of the globe. They generally have high solar potential, isolation in the range of 6-8 kwh/m^2 per day except in regions of extensive cloudiness. For example, winter insolation in Egypt averages 5 kwh/m^2 per day and in summer above 8 kwh/m^2 almost double the insolation in Alburquerque, New Mexico which is considered a desirable and economic location for solar energy. At the same time, these hot dry climates often pose extreme environments, including sand storms, dust storms, occasional torrential rains, and other events which require the development and construction of rugged and long lasting solar components.

Solar energy has been traditionally utilized throughout the developing world for crop drying. Solar water heaters have made scattered appearances at various places at various times in developing countries. Attention to solar effects has dominated the architecture in many African villages over a long period of time. Solar equipment is produced in Jamaica, Brazil, Tanzania, India and many other countries. Consequently, the utilization of solar energy is not unknown in the developing world, and we consider here more the expansion of solar utilization into areas of demand typically supplied by fossil fuels.

Estimating the market penetration of a variety of solar devices is difficult for several reasons. In principle, an estimate of market potential would be based upon economic comparisons between solar and competing devices, the projected growth in basic human needs and/or service demands, and technology or production limitations. However, two primary factors interfere with this rational process. First, for many of the new uses in the solar field, there is too little field experience to project cost with any certainty. Second, developing countries data on the growth of demand in industry, commercial activity, and residences for the type of energy that can readily be supplied by solar devices is often not known with any certainty. As a result, our estimates of market penetration for solar technologies are based on a rough comparison of their economics against competing devices and the consideration of technical and or instutional constraints which permit a rough judgment of the eventual potential for utilization of solar devices in specific applications.

Water Heat

Solar technology for hot water heat, particularly low temperature needs, can be considered relatively well developed or standard technology today. There are readily available systems from commercial manufacturers in both the developed and, in many cases,the developing countries. Low temperature

water (less than 100° C) may be supplied by simple flat plate collector systems. These have flat blackened surfaces with a glass cover. The heat transfer may be air or, most often, water or another liquid. These systems might have small pumps or rely upon convection circulation. Higher temperatures (to 300° C) may be derived from point focusing collector systems, though in this case the use of a tracking mechanism for the mirrors and other equipment results in what must in this context be called high technology. The lower temperature hot water systems are readily adapted to in-country manufacture. It is estimated that 85% of the materials, equipment, and labor might be locally supplied; thus the employment and foreign exchange aspect of solar water heat is quite desirable from a developing country's point of view.[30/] Present costs for solar collectors are in the range of $10-20 per square foot, or $300-600 for typical residential installation. Consequently, such systems are considered highly cost competitive at present and their economics is likely to improve somewhat as mass production continues.

Industrial process heat is a primary area of application for solar water heat. Light industry (food processing, textiles, etc., excluding mining and metals, chemicals) typically consume 20% of national commercial energy use in developing countries, and commercial fuel use is mostly oil.[31/] At the same time, about 60% of industrial process heat is hot water, mostly below 300° C.[32/] The limited amount of high temperature steam would require sophisticated solar technology and is not considered a likely application in the time frame to the year 2000. However, the large requirements for hot water at lower

temperatures may be easily and economically satisfied by flat plate and/or axial focus solar hot water systems. Egypt, for example, follows this pattern and wide utilization of solar water heat could reduce oil requirements by almost 10 percent.

Payback calculations for industrial process heat applications show their investments are not apt to be made unless the payback time is less than 5 years. On the basis of industrial experience, this level of payback has been shown to lead to quite slow rates of installation, but the relative economics of industrial process heat applications is expected to improve as other fuel prices rise. If all new growth in industrial energy demand (assuming 7% annual growth) were supplied by solar water heaters, the market penetration by the year 2000 would approach 75 percent. The United States market penetration estimate for the year 2000 is 50 percent which we take as a more realistic limit. There is, of course, some potential for waste heat drived from higher temperature processes, and since that technology should be available to LDCs by 1990, our estimate of the potential for solar thermal applications is conservative.

For a typical country which is well endowed with solar energy, and in which 30-40 percent of industrial oil use is for process heat accessible to solar substitution, this analysis indicates that 2 to 4 percent of national oil consumption would be saved by 2000.

The commercial and residential sectors consume roughly 20 percent of national oil. Approximately 20 percent of this is utilized in water heat applications. The market penetration analysis for the commercial and residential sector is much as above. At present, most urban dwellers in Egypt, for example, have water heat. In rural areas less than half of households use water heat though this is expected

to rise to all households by the year 2000.[30/] The economics of residential solar heat is quite favorable now, and the technology is finding wide application in Jamaica and other countries. Increasing use of hot water is also expected through increasing health standards, hospital use, and the general improvement of living standards. With an annual growth rate of 6 percent, we assume an upper limit of 50 percent for the market penetration. This leads to a potential oil savings of 1-2 percent of national consumption in 2000.

There is relatively little need in developing countries for heating; cooling remains a luxury for the few although it can be important in more advanced countries and tropical countries with a large tourism sector. Given the high cost of solar absorption cooling systems, their impact upon a relatively small demand for cooling in the developing countries would seem to be minor on a world scale.

Central Station Thermal Electricity Generation

Central station solar thermal electricity generation is suggested as an alternative to present means of electricity generation. A large field (perhaps 100 acres) of collectors is focused to a point. These collectors are ten square meters or larger and computer-controlled to track the sun. A tall tower with high temperature boiler (above 300° C) collects the solar energy which is fed to a turbogenerator for electricity. This system also contains condenser and hot liquid storage and possibly a fossil back-up system. While much of the system is conventional equipment, such as the electric

generator, very high energy density at the focus requires the development of special equipment for the boiler. In the early 80's, it is expected the United States will demonstrate 5 MW central solar systems, which entail about 100 acres of collectors and a 20 story tower for the receiver.[8/] Following that it is expected that a 100 MW demonstration system with a 1000 foot high tower will be built. A cooperative program with Spain will also demonstrate this type of central station solar thermal electricity generating technology. It is not until the mid 1990's that a commercial demonstration plant is projected to be built. Consequently, until the mid to late 1980's, it will be difficult to have reliable cost estimates or to formulate a realistic idea of the time scale for the development of the technology. Smaller scale systems supplying 100 KW are currently available from Italian firms. These are suitable for decentralized applications, but costs presently make such systems only available as research tools. The most optimistic estimated costs for central solar by the mid 80's are around $2,000 per kW.[33/] The technology content of central solar electricity technologies is largely that produced in the developed countries. The estimated import content in such systems would typically be 80 percent with only 20 percent of system equipment, materials, and labor supplied in-country.[30/] In this regard such systems contrast with solar water heaters which could rely mostly upon local production and labor.

The uncertainty of both technology cost and the time frame for technology development make an estimate of market penetration very uncertain. An upper limit would be set by electric system reliability considerations (estimated as 15% solar for Egypt).30/ Given the economics and state of the art of this technology, however, we would judge that in the most favorable conditions a contribution to electricity supply by 2000 of greater than 5 percent is unreasonable. At best this represents a one percent reduction in LDC oil demand in 2000.

Photovoltaic systems, discussed below, also have the potential for central station electricity generation but we would expect only a similarly small contribution by 2000.

Decentralized Electricity

The utilization of photovoltaic devices is often suggested for decentralized, meaning mostly rural, applications. While these systems tend to be expensive, their applications seem most likely in rural areas because it is here they can become cost competitive with the high costs of rural electrification for public use and irrigation.

Photovoltaic devices are small semiconductors which convert sunlight directly into direct current electricity. The present costs for photovoltaic devices are about $6.00 per peak watt, but with mass production and technology breakthroughs is expected to drop to $2.00 per watt by the early 1980's. This would bring electricity system costs to about $3,000 per peak kW (1978 dollars), which becomes cost competitive for

delivery of electricity to some uses in rural areas. Although support structures, etc. could be manufactured in-country, the major part of photovoltaic electricity systems would probably be imported in most LDCs.

Decentralized solar thermal electricity relies upon moderate temperature axial-focus solar devices. Low temperature steam can then be used to drive a steam engine for irrigation pumping or a small turbine for electricity generation. The cost range for such solar thermal systems is presently comparable with that for photovoltaics. Both photovoltaic devices and decentralized solar thermal are expected by the mid or late 1980's to be cost competitive with diesel electricity generation in rural areas with $1.50 per gallon fuel.[13/]

Rural electrification continues to remain a high priority in many developing countries. In 1971 12% of rural people were served by electricity. Targets would have this double to 25% by the year 2000. (Although this is the level at which electricty is "available," only a fraction of this population will be able to afford electricity service). In Egypt, for example by the year 1977, 2400 of 4000 villages were already electrified. But the projected addition was about 600 villages in 1978 alone at a cost of $8,000 per village. [30/] In the rural electrification programs, the primary uses are street lighting, public buildings and irrigation, with some electricity going to residential customers. The difficulties associated with the expansion of grid-supplied electricity are due mostly to the cost of long distance transmission and distribution lines, particularly given the poor load factor in rural areas.

The market penetration of photovoltaic and/or solar thermal systems in decentralized applications for rural areas is difficult to estimate. At present, there is substantial debate regarding the economics of grid-expansion versus diesel electric generation in rural areas, which suggests comparability between these two costs. The decentralized photovoltaics are competitive with diesel generation in rural areas, at least for estimated costs in the early 1980's. In addition, the rural load factor is less than 10%, whereas the system load factor overall is about 50%. Consequently if installed system costs for the total grid are $1,000 per kW (excluding even the additional transmission cost to rural areas), the difference in load factor raises this to about $5,000 per kW of equivalent capacity cost installed for rural customers. At this cost level, the solar technologies can be more economical than grid central or diesel generation. The capital costs to individual users of such systems are large, however, particularly given the limitations of rural income. In practice, decentralized electricity will find use in water pumping and public uses, and we assume that by the year 2000 photovoltaic devices could displace at most 50 percent of energy consumption for these end uses. This would lead to a savings in oil in typical countries of 1-2 percent. Higher penetration could be expected only under either direct government purchases and installation and/or an aggressive tax credit policy to encourage use.

D. WIND

On a global scale those countries which lie somewhat north or south of the equator (particularly in the regions of 10°N - 20°N and 10°S - 20°S) are generally well endowed with wind resources. In these regions the "trade winds" tend to be steady and strong. Island and mountainous countries and regions also tend to have greater wind resources than average. Thus, because of their typical location and geography, developing countries in general are somewhat favorably endowed with wind energy potential. Nonetheless, wind as a resource is highly variable with location, season and due to random fluctuation making it a difficult resource to assess, particularly given the very sparse information currently available on the wind regime in individual countries.34/ Although in some applications the intermittent nature of electricity generated by wind machines is acceptable, in general electricity storage, for example in batteries, is required. For mechanical applications of wind machines, for example in irrigation pumping, storage may in effect be provided by the overall system.

It is usually considered that wind speeds in excess of 10 mph are required for practical wind applications. Wind machines may be built with either vertical or horizontal axes. The horizontal axis machine, essentially a propeller on a shaft, has been the traditional means of capturing wind energy in the past, but does require the machine to be pointed into the wind. Vertical axis wind machines on the other hand accept wind from any direction.35/

Wind machine technology is still under active development despite the fact that mechanical water pumping is an ancient use. Wind turbine electric generators in the 50 kW class are available as off-the-shelf equipment. However, it is estimated that megawatt class machines will not become commercially available for a few years. Cost estimates are approximately $4,000 per kW installed for 6 kW machines (rated at 29 mph wind), but are expected to decline somewhat with larger machines to perhaps as low as $500-$1,000 per kW installed.[8/] At these costs for electric generation, wind electric is cost competitive with diesel generation in specialized and remote applications where storage costs are not excessive.[36/] Also, wind technology is not highly sophisticated and can rely extensively upon indigenous country production facilities. It is estimated, for example, that at $4,000 per kW installed perhaps 75 percent of the cost could be local. Import requirements generally could be limited to blades, electrical equipment and some materials. Consideration of the shadow prices of labor and foreign exchange in wind technology could thus substantially enhance the competitiveness of wind technology.

The market penetration for wind electricity is difficult to estimate for several reasons. First, there is only limited operating experience with such machines and this has generally been limited to those on the small side of the capacity range. Second, as mentioned above, there is very little information on

detailed wind regimes necessary for assessment. Nevertheless, recent assessments in Puerto Rico, Peru and Egypt can give some idea of typical market penetration rates.

Wind turbine generators for electricity production in developing countries have two potential markets. First, they provide an economical substitute for diesel electric generation in carrying out rural electrification programs. Second, they can be used in grid-connected applications to reduce thermal generation requirements. In Peru, the electric system consists of several independent grids, and there is considerable difficulty and expense in extending the grid into rural areas. Based upon the easy availability of small wind m chines by the early 80's, it was estimated that some 200 units of 10 kw capacity and 10 units of 100 kw capacity could be reasonably introduced annually into the system. 37/ This constitutes 3 MW of wind capacity annually whereas the aggregate growth in electricity system capacity is about 180 MW annually over the time horizen to the year 2000. Consequently, both technical limits on the availability of equipment as well as the need to develop a basic experience with wind turbine generation and the availability of alternatives were construed as limiting the potential impact by the year 2000 to less than one percent of capacity.

Egypt has two coastal areas in which winds average 13 MPH. These are well suited to the introduction of wind turbine generation, and it was estimated that by the year 2000 there could be almost 6000 5 kW machines and perhaps 3000 100 kW machines.31/ These are viewed as being grid-connected applications and would bring the wind turbine generation to about 1000 MW in a total electric grid (mostly hydro) capacity estimated for the year 2000 at 23,000 MW. Consequently, even under favorable government initiatives in the field, wind generation is a small contribution to national energy consumption.

Wind turbine generation is most suitable for grid-connected applications where it will substitute for oil-fired thermal generation. Puerto Rico has about 11 mph steady winds in its coastal areas and an electricity system fired almost entirely by oil. While MW machines are not expected to be available for several years, a recent wind study suggests immediate implementation and substantial wind development over a six-year period, initially using the smaller machines. It was estimated that an aggressive government program could install 300 MW of wind turbine generation by the late 1980s, or 10% of national electrical grid capacity. 38/ The estimated cost for the program is about $1000 per kW installed and it would displace about 670,000 barrels of oil equivalent, or about one percent

of national oil consumption by 1990. This is clearly an ambitious goal but, on such an island under circumstances of rapid electricity growth it is not totally unrealistic to consider replacing 30 percent of electricity generation, or 5-7 percent of oil consumption by 2000.

Wind irrigation pumps have been in common and successful use in a number of developing countries including Tanzania, Uganda, Argentina and Zambia. In a number of instances where such pumps have not been successful, for example in Mali, Somalia and regions of Uganda and Tanzania, it was the result of lack of personnel and/or materials to carry out maintenance.17/ Wind pumps are often used to open marginal agricultural areas or bring new irrigation to existing producing areas and it is not clear that such uses replace oil. Nevertheless, in some cases one can estimate the potential of hypothetically substituting wind pumps for current diesel sets. In Egypt, for example, about 25 MW of diesel water pumping is under government control and another 280 MW in private hands (40,000 units of 7-15 HP) If half of this water pumping were taken over by wind machines, about 300,000 barrels of oil would be saved each year, or only 0.5 percent of current use. Generally, despite the importance of irrigation pumping, only a small portion of national oil consumption goes to that use.

This analysis leads to the conclusion that a wind program in a country well dendowed with wind resources and whose electric system depended on oil could reduct its oil consumption by roughly 5-7 percent by 2000. We estimate the global scale factor for wind substitution to be not more than 0.20, giving a global contribution of this technology of 1-1.5 percent of oil consumption.

E. SMALL SCALE HYDROPOWER

Hydropower represents a significant resource of electricity supply for developing countries. Even now, about 44 percent of LDC electricity output is produced from hydropower (contrasted to 24 percent for the developed countries) and a considerable fraction of untapped hydropower exists in developing countries. The economic incentives for developing large-scale hydropower are clear and the institutional mechanisms are well established. Thus, in the context of this paper we do not consider large-scale hydro as a potential new substitute for oil demand.

Such is not the case for small-scale hydropower. Although pilot units have been installed in a number of countries, only in the People's Republic of China has there been a significant level of implementation. Estimates of installed capacity vary around 50,000 units as of 1974. They range in size from less than 3 kW and average around 35-50 kW.[39/] The capacity in small hydropower may represent as much as one

third of China's total hydropower capacity supplying over 50 percent of rural electric power needs.[40/]

Hydroelectric turbine units in the range of 500 watts to 50 kW are readily available commercially with costs ranging from $500/kW to $300/kW depending on size and characteristics. Turbines and generators are built in India and Nepal and possibly other developing countries. The cost of various other components of a small-scale hydro system could multiply the total cost of the system by a factor of 2-6[41/] but the costs are still competitive with decentralized generation based on diesel fuel, as demonstrated in studies in Nepal, Peru, and Tanzania.

As an example, one can consider Peru as a country which is well endowed with small-scale hydro resources. The Department of Energy study of Peru[31/] estimated that of a total of 3000 villages in the mountains and jungle, one hundred of these had populations at between six and ten thousand persons and 72 of these were close to significant hydropower sources. Ninety-five percent at present have no electricity, and others are supplied primarily by diesel. The desired installed capacity per capita is projected at 30 watts. An expansion plan for small-scale hydro calls for 17,000 stations of 30 kW, 400 stations of 120 kW, 90 stations of 270 kW capacity by the year 2000. Total installed capacity would then be 120 MW, though with the typical rural load factor of 10 to 20 percent total electricity generation is

still quite small, 210 Gwh in the year 2000. Small mining establishments offer another possible user of small-scale hydroelectricity in Peru. These might add a further 180 Gwh of electricity demand by 2000. If all of this electricity were supplied by diesel or gas generators it would require approximately one million barrels of oil, or somewhat less than one percent of projected oil demand in 2000.

In countries that are well endowed with hydro resources, one cannot assume that small-scale hydroelectricity will replace electricity generated from oil. It is likely that transmission from large-scale hydro electric generation will be replaced. Thus, in estimating the potential for oil replacement we assume that small-scale hydro can replace 0.5 percent of oil demand by 2000 in countries well-endowed in this resource.

In terms of global potential, hydro resources are quite unevenly distributed throughout the developing world. Latin America is the best endowed and the Peru example may be applicable to a number of other Andean countries. Our estimate of a global-scale factor need not be highly refined, however, for even if we take a generous figure of 0.4, the global contribution is only .2-.4 percent in 2000.

Direct mechanical use of water power is one of the earliest forms of controlled energy use by man. They are relatively widely used to grind grain in a number of mountainous countries but have quite limited applications relative to

small-scale hydroelectric power. The potential impact of this technology is not judged to be significant in the context of this assessment.

F. GEOTHERMAL ENERGY

Geothermal resources constitute an important potential energy source in many parts of the developing world. While it is a local phenomenon associated with either volcanic activity or hot rock and steam deposits near the earth's surface, such areas are widely distributed around the globe. The use of geothermal energy for industrial process heat, residential-commercial hot water, and for electricity generation has proven quite economical compared with more traditional uses of fossil fuels. Experience with geothermal resources is relatively limited, however, and exploration of potential deposits is still inadequate. Nevertheless, recent cost increases for fossil fuels have stimulated greater interest in evaluation and development of geothermal energy.

Geothermal energy is most often developed to supply electricity, since distribution of low temperature heat is difficult and costly. Power stations are in operation in Mexico, El Salvador, the Phillipines and elsewhere in the developing world as well as in developed countries such as Italy, the United States, and most notably Iceland where utilization includes district heating and hot water in addition to electricity generation. 42/ Geothermal fields have been found in Chile, India and Kenya. As many as 80 developing countries have

been identified by the UN as having economically exploitable resources.[43/] The World Bank lists the following as having significant geothermal potential:

Mexico	Turkey	Cameroon
Guatemala	Iran	Rwanda
El Salvador	India	Burundi
Nicaragua	Indonesia	St. Lucia
Venezuela	Philippines	Dominica
Boliva	Yemen A.R.	Martinique
Chile	Ethopia	Guadeloupe
Argentina	Kenya	Solomon Islands
Costa Rica	Tanzania	

The most common geothermal resource is hot water, usually brine and steam at temperatures up to about 250° C.

Typical electric generating stations to utilize this source are 5-100 MW in size and a geothermal field might contain several hundred megawatts total potential. The life of a field is highly uncertain but in many cases is thought to exceed 50 years. Typical installed costs for geothermal electricity generation are $1000-$2,000kW.[44/] However, since there is no fuel charge, electricity is available at a busbar cost of 2-4 cents per kWh. Geothermal electricity is then comparable to hydroelectric power and for cheaper than diesel, coal, or oil - fired thermal power in developing countries.

As an example of a country well-endowed with geothermal potential we have chosen El Salvador. With a current capacity of 50 MW, that country is planning on having approximately 25 percent of its installed electric capacity in geothermal power by the end of the century.[45/] If this were not installed, national oil consumption would increase by about 5 percent, assuming it would be replaced by oil, rather than hydro, a somewhat dubious assumption. In fact, many countries in which

there are geothermal resources, there are also hydro resources. Thus the 5 percent estimate should be lowered somewhat - say to 3-4 percent - to reflect that fact.

An even more ambitious geothermal program is under way in the Philippines. With a current installed capacity of 220 MW, the national objective is 1430 MW by 1983, representing over 20 percent of installed capacity at that time.[46/]

On a global scale the total geothermal resource is very large[47/] but due to the limited extent of current exploration, only a small fraction can be expected to be exploited by 2000. Considering the possibility of using lower temperature brine deposits in the late 80s and 90s, we have defined a global scale factor of 0.2 leading to a total LDC potential of 0.5 - 1 percent of oil demand.

G. OTHER NEW TECHNOLOGIES

There are a number of other technologies such as tidal power, ocean thermal gradients and wave power which we have not discussed separately since their potential impacts are very uncertain, localized and probably quite small. Nonetheless, to demonstrate a degree of technological optimism in the 20 year time scale of this study we have taken credit for up to 0.5 percent contribution to oil reduction from these sources.

IV. THE POTENTIAL FOR INCREASED ENERGY EFFICIENCY

A. SUMMARY

Conservation, a subject not widely discussed in the context of third world energy policy, appears to be at least as promising as all the renewable technologies taken together in terms of its capacity to replace projected LDC oil demand[48/]. Our estimates show that between 10 and 20 percent of projected 2000 oil demand could be "met" through conservation, primarily in the industrial and transportation sectors of the more advanced LDC's. Such savings could be brought about primarily through improvements in efficiency, and would not require hardships or slowdowns in economic growth. Indeed, since we have considered only cost-effective measures, economic growth could be enhanced through these conservation strategies.

Our estimate of potential savings through increased efficiency programs is conservative because it represents incremental savings that could be achieved over and above purely price-induced reductions. Rapidly increasing energy prices - particularly for imported oil - can be expected to reduce energy and oil demand through normal market mechanisms; the extent of such reductions is, however, uncertain and this uncertainty accounts in part for the year 2000 LDC energy demand projection range (20 - 25 MBD) that we employ in this paper. In this section we discuss additional savings in oil demand that could be achieved through accelerated, vigorous conservation programs aimed specifically at displacing demand for imported oil. Such programs might include governmental policy

changes (such as regulation of some end-uses), energy-conscious development planning, and institutional changes to alter the investment climate in favor of conservation. Table IV.1 expresses conservation potential for 1985 and 2000 broken down by end-use sector. All figures are expressed as ranges because of the high degree of uncertainty about prices, economic conditions and capital availability in the future. As the table indicates, conservation potential is quite small(2 - 5 percent) for the near term (five years). Even this potential contribution to meeting 1985 demand is significant, however, because it exceeds the potential of any realistic supply option, whether emphasizing fossil fuels or renewable sources. In other words, conservation may be a particularly attractive option for LDC's and for aid-giving organizations because it can achieve rapid results.

B. INTRODUCTION AND DEFINITION OF CONSERVATION

Until recently, the term conservation has been perceived as simple "doing without" or doing with less. The confusion has been increased by some proponents of appropriate technology who have gone beyond advocating "soft paths" to suggesting that saving energy is somehow morally superior to producing it. Recently, however, technical and policy documents have tended to treat conservation in a manner more firmly grounded in its usual meaning for both physics and economics - that is, in terms of efficiency. In this section, the term energy conservation will be defined broadly to include not only a reduction of energy use through behavioral changes, (e.g. driving fewer miles, car pooling, changing thermostat settings, etc.) but also - and primarily - improvements in energy productivity or efficiency, which is a measure of the output of useful work per unit of energy input.

TABLE IV.1

ESTIMATED LDC PETROLEUM CONSERVATION POTENTIAL
(% of oil demand saved,
compared with current
policy case)

	1985	2000
Large Industry	5-10	10-20
Small Industry/Commerce	2 -5	5-10
Residential	1	3-8[a]
Transportation	1-5	20-30
Weighted average[b]	2-5	10-20

a/ Much of the residential sector savings come through electricity savings

b/ Weighted average takes into account the absolute demand levels in each sector for all LDC's.

Conservation in its more limited sense is seen by many in the developing world as an impediment to growth, while productivity is perceived as enhancing or accelerating growth.

One of the key ideas underlying the identification of opportunities for increasing energy efficiency is the concept of energy service demand. A service demand recognizes that in demanding energy, the consumer desires not the fuel but the benefit or service that the fuel provides. A simple example of this is the provision of heat to a room - the occupant desires a room at a comfortable temperature, and is indifferent as to how that is achieved - except in that he would like it at the lowest cost. In the transportation sector, passenger miles represent a service demand (the consumer wishes to get from point A to point B at the lowest cost given comparability in comfort and safety). In the industrial sector, the need for steam is an example of a service demand; a process which requires steam is essentially the same whether the steam is generated by a coal-fired boiler or is recovered heat from some other process. Service demands are simply defined in conventional energy units and can be theoretically derived after accounting for all losses which occur in the conversion equipment and/or thermal envelope.

Defining energy-consuming activities in terms of service demands allows the planner to provide the service (whether it is space-heat or mobility) by a myriad of alternatives. Given a degree of competition, the consideration for selecting one alternative over another is usually the cost of a particular alternative--not just the initial cost of the conversion equipment or hardware but the total cost over the lifetime of the

equipment including the cost of fuel and maintenance--commonly referred to as the life-cycle-cost (LCC). Industrial managers, transportation planners and building architects or engineers are only now beginning to apply life-cycle cost analyses widely to energy-related investment decisions in the industrialized countries. In LDC's,the method is less frequently used but might, if widely adopted, contribute to substantial energy savings.

The least-cost framework and life-cycle cost calculations provide truly cost-effective results only when actual costs are used; if governmental policy deliberately holds the prices of certain fuels below their replacement costs through subsidies, the least-cost model obviously favors those fuels even though they many not be the best choices in terms of resource and foreign exchange availability. Clearly, however, the general principle of minimizing the cost of a given service is fundamental enough to cross social and cultural boundaries and be a useful framework for assessing the potential for increased energy productivity in the LDC's.

C. INDUSTRY

Although all LDC's are industrialized to some extent, industrial-based oil demand is heavily concentrated in just a few countries. Just 8 countries consume 60% of total oil used by non-OPEC LDC's, and approximately 35% of those nations' oil consumption can be attributed to industrial use.

Service demands met by energy in the industrial sector include:

- steam (for driving turbines and other machinery);
- direct heat (whether low-temperature for food processing, or high for steel making);
- mechanical drive (for machines, gears, wheels, etc.):
- space heat (for factory and warehouse buildings).

Energy use in the industrial sectors of developing countries is dominated by the basic material goods industries which are energy intensive--principally iron and steel, nonferrous metals, chemicals, fertilizers, cement, refined petroleum products, pulp and paper, and clay and glass products.

Since most of these plants were designed with help from the developed countries, and energy prices were not foreseen by experts anywhere to rise as rapidly as they did, there appears to be as much potential for making reductions in energy use through cost-effective retrofits in LDC's as there is in developed countries.

According to two recent unpublished World Bank studies,[49/] the energy intensity of LDC economies (measured as energy use per dollar of GDP) is 15-20 percent lower than that of industrialized nations' economies. This is due to the structural differences in economic activity between the two country groups. Within the industrial sector, however, LDC's are approximately 20 percent more energy-intensive than the OECD nations. There are two possible explanations: 1) the greater share of heavy and energy-intensive industry within LDCs' industrial sectors, and 2) lower efficiency of industrial energy consumption in LDC's. The former certainly

accounts for part of the difference; the latter, while difficult to document, also appears likely in at least some industries due to technological lag, diseconomies of scale, shortages of capital to substitute for energy, and other factors. Government subsidies on industrial fuel prices may be major contributors to LDC industrial energy intensity in many countries.

Industrial conservation measures can be grouped in three general categories:

(1) Relatively easy to implement administrative and information programs, typically achieving 5 to 10 percent savings. These programs create energy awareness and reduce energy use which is controlled by the individual (a plant operator, for example). Such programs are often called "housekeeping" measures and results are usually achieved within a short time frame.

(2) Re-equipping plants, buildings or systems through small incremental investments for an additional 5 to 15 percent savings on average. Examples of such investments include waste heat recovery projects, or modifications to industrial processes. Results of these efforts may be achieved after a period of several months.

(3) Major technology or system changes through major capital expenditures, for savings of 20 to 90 percent, depending on the nature of an industry, plant, building or other energy-consuming system. These investments often require long lead times for implementation, sometimes several years.

According to reports of the U.S. Industrial Energy Efficiency Improvement Program (administered by the Department of Energy), improvements in U.S. industrial energy, efficiency have been achieved from 1972 to 1979 primarily through easily-implemented administrative and small investment programs--in other words, to a large extent through "housekeeping". The impact of "housekeeping" is particularly important, because this type of saving can result from improved operation of even the best modern technology. Thus the existence in a developing country of a modern plant with the most up-to-date equipment and processes does not in itself guarantee the efficient use of energy. As well as actual operation, the standard of maintenance of energy-consuming facilities is important for energy efficiency. It is therefore the manner in which the facility is operated which can determine to a large extent the level of energy efficiency achieved.

Beyond "housekeeping" we may expect opportunities for energy efficiency improvements to arise through actions such as the following:

1) Raw material and product specification changes;
2) Improvements to existing technologies and processes, including better instrumentation and control systems, improved heaters, boilers and furnaces;

3) Recycyling and use of waste materials, including waste heat;

4) Improved systems for electricity supply and utilization, including on-site co-generation of electricity and steam;

5) Changes in industrial processing methods; and

6) Equipment R, D & D, leading to new industrial technologies.

The benefits to energy efficiency resulting from these measures will vary from industry to industry, or plant to plant, according to current energy efficiencies and to the scope for retrofitting new technologies. Most improvements on a sectoral basis result from the combination of many small improvements in all aspects of energy use. Continued improvement over the long run will require appropriate incentives for the application of the best available technology, and will require significant continuing expenditure on R & D (and on associated technology transfer to developing countries) in order to provide the most efficient technologies and processes.

Although the magnitude of possible improvements in energy efficiency is highly specific to the situation in a particular country (and indeed to a particular industrial plant), the potential impact of conservation in developing countries is perhaps best indicated by some actual examples of conservation and by comparisons of energy consumption in particular industries in various countries.

Some idea of the magnitude of savings to be expected through conservation programs in the industrial sector is given by the U.S. "Targets" program. For the period January 1, 1973 to January 1, 1980, the following improvements in energy efficiency were set as targets for ten major industries:

INDUSTRY	PERCENT IMPROVEMENT TARGET (Total energy)
Food	13
Textile mill products	25
Paper	23
Chemicals	17
Petroleum products	20
Stone, clay and glass	16
Primary metals	14
Fabricated metal products	25
Machinery	17
Transportation equipment	18
Weighted industry average	17

According to data for 1979, most industries are expected to meet their targets, some to exceed the targets by several percentage points. Analysis of reports of conservation programs submitted by corporations to the Department of Energy[50], as well as forecasts of conservation potential made prior to setting the targets, suggests that the first ten percent of savings are typically attributable to housekeeping, and the balance primarily to programs involving minor capital investment at existing plants. Major capital programs (including new plants), will not have a large effect on conservation in the seven years to January 1980, because of long lead times for implementation. Savings from "housekeeping" alone are not likely to grow significantly after the early 1980's, while the savings attributable to major new investments will become increasingly important.

The aggregate U.S. experience in industrial energy conservation has been quite dramatic. Between 1973 and 1978 industrial output in goods and services rose 12 percent while industrial use of energy dropped by more than 10 percent - an overall improvement in energy productivity of about 22 percent. Although part of this improvement may be due to changes in the mix of industrial activity, most of it can be attributed to real productivity improvements.

There are examples of industrial conservation in practice in some LDC's, particularly in energy-intensive industries. One survey of Kenyan energy consumption revealed that a Nairobi cement factory employing the wet kiln process was able to reduce its oil consumption from 6 million Btu's per ton of cement in 1975 to 5 mm Btu/ton in 1977 by instituting a pre-drying process that employed waste heat. The same survey found that housekeeping improvements in a Kenyan tire factory reduced energy consumption from 1.09 khw of electricity plus 15,000 Btu's of direct oil per ton of tire in 1975 to .74 kwh plus 9,650 Btu oil per ton in 1978.[49/] It is notable that both the cement plant and the tire factory were able to achieve <u>improvements in energy efficiency</u> which lowered costs per unit of output.

Comparative international figures compare the situation in Kenyan cement plants with several plants in Peru and in certain developed countries. These figures are shown in Table IV.2.

Table IV.2

COMPARATIVE ENERGY INTENSITIES
IN CEMENT PLANTS

	Kiln Fuel K Cal/Kg. Cement	Electricity KHW/tonne clinker
Kenya (1975) Plant A	1350	100
(1977) Plant A	1125	100
Peru (1976) Plant A	900	115
Plant B	1440	N/A
Plant C	1215	137
Plant D	1196	135
National Average	1111	137
Germany (1974)	800 - 1200	118
Italy (1974)	900	127
United Kingdom (1974)	886	127
United States (1974)	1358	163
"Best modern technology"	850	110 - 120

Fuel and electricity consumption figures in the two developing countries compare quite favorably with other countries but, compared with "best modern technology", the energy consumption of the Kenyan and Peruvian plants is quite high. The potential for improving energy efficiency in the cement industry is therefore good, both from the improvement of existing plant operations and from the commissioning of efficient new plants, probably of large capacity, in the next few years. The advantage of these new plants may well be compounded as inefficient old plants are shut down. Conservation programs to improve the existing plants and, through technology transfer and training efforts, to ensure that the best modern plants are installed and properly operated, can therefore contribute effectively to improving the national energy balance.

Further corroboration of the potential for significant energy savings is provided by the experience last year in Brazil where industry was required to reduce oil consumption by 10 percent. This was accomplished in a few months with apparently no significant impact on output.

For the short to medium term, then, most of the energy conservation savings will come from retrofitting existing facilities and systems. For the longer term, the largest savings will come from commissioning new and expanded facilities which are designed to incorporate the latest technologies ensuring the most efficient use of energy. This is particularly important for oil-importing developing countries, because recent experience indicates that oil consumption rises faster than income as the industrial sector grows in LDC's.

Effective R D & D programs can also make a major contribution to reducing petroleum-based fuel dependency in the industrial sectors in the medium to long-term. Because private sector research is conducted to create, maintain or enhance competitive advantages in the marketplace, there is often a role for government-sponsored programs which can focus on energy efficiency as opposed to other factors influencing privately-funded R&D, such as cost reduction and improved return on investment.

Economic Aspects of Industrial Conservation

Housekeeping activity usually requires little capital investment. Some funds and personnel are, of course, needed for estab-

lishing and maintaining energy awareness and other training programs, but the payback from these activities is usually very attractive. The most important requirement of housekeeping and awareness programs is a full and continuing commitment by senior management, and by senior policy makers in government agencies, to the concept of energy conservation. Without this commitment, experience shows there is little chance of success.

Beyond basic housekeeping, capital investment will be needed to effect worthwhile savings. Each project is normally evaluated and its return on investment established. Acceptability of this return is an individual matter for the owner of the facility, which may be the government: typical criteria set by large private sector companies are in the range of 15 to 25 percent return per year. Sometimes the criterion of acceptability for a project is set in terms of a simple payback period: two to three years is often quoted for medium-size projects, longer for larger investments. Sometimes the rate of return criteria for energy conservation projects are quite stringent, more so than the required rates of return for new plants or expansions, for example, despite the fact that conservation investments are often less risky than expansions which must rely on market development to show profitability. There may be an opportunity for training in project evaluation to contribute to improving the extent of conservation in developing countries, as indeed there is in many sectors of the industrialized world.

Energy conservation investments must compete with other investment opportunities for the limited amount of discretionary capital. Higher priorities are often assigned to projects other

than energy conservation, such as plant or system capacity expansions designed to increase output, employment and foreign exchange earnings through export expansion. On the other hand, energy conservation projects are likely to be favored by a government which faces severe oil-import burdens that might actually be increased beyond the level of export earnings attributable to plant expansion. Industrial investment decision-making must be based on all relevant factors, including energy implications on a national scale.

The above discussion pertains almost exclusively to large-scale industries, particularly those that are energy-intensive.

Small scale industries such as leather, handicrafts, weaving, electrical assembly, etc., constitute a large part of the industrial sector in many LDC's. They tend to be labor-intensive, and when they use energy, it is principally electricity for mechanical drive or electroplating. There is little oil to be saved directly in the small scale industries, or in the "informal" sector which comprises domestic services, manufacture and repair by craftsmen, street vendors and recycling. Electricity savings at the point of generation and/or transmission are possible, however, and these are discussed separately below.

D. TRANSPORTATION

Transportation, with urban transportation its largest component, typically accounts for 20-40 percent of commercial fuel use and 25-50 percent of oil demand in LDC's with some individual countries using up to 75 percent of all oil demand for transportation. The sector is, therefore, an important target for cost-saving technologies.

On the average, LDC transportation is 40 percent more energy-intensive than transportation in the OECD nations,according to the World Bank. This seems surprising, given the greater share of energy-intensive transport modes (automobiles and airplanes) in the industrialized nations and the large number of bicycles, motorcycles and muscle-powered carts in LDC's. The difference appears to lie primarily in freight transport, and in the lower value per freight ton in LDC's, rather than in lower efficiencies. Yet conservation potential does appear to exist in LDC transportation, in both the passenger and freight subsectors.

Urban transport comprises the major share of LDC passenger transportation, and cars and buses together make up about 80 percent of urban passenger transport. Buses, although they represent only a small fraction of vehicles on the road, account for about two thirds of all trips in LDC cities. Severe traffic congestion in many cities lowers the fuel efficiency of both cars and buses in urban passenger transport; longer trip duration, stop-and-go driving, and frequent idling could all be reduced through better planning of transportation systems and of land development patterns (the latter already notable for the same sprawl patterns as those that are so widespread in the U.S. as well).

At first glance, it seems logical to expect that increasing the efficiency of the auto fleet and encouraging (or even requiring, by banning autos in inner city areas) switching to buses might result in significant oil savings. In practice,

however, such a solution is unlikely to work, particularly in the short term. A significant fraction of LDC cars are small and therefore already considerably more efficient than American gas guzzlers. They also have considerably longer lifetimes; since labor is cheap for the most part, cars are maintained in working condition two to three times longer than they are in the developed world, making fleet turnover a very long-term proposition. Retrofitting cars to improve gas mileage is not usually cost-effective. Switching to buses in the short-term also presents significant difficulties, since buses in LDCs are usually crowded, inadequate in number and subject to frequent breakdowns because of overloading and insufficient preventive maintenance. In addition, cars are a symbol of wealth and success in LDCs as they are elsewhere, and the upper classes, who alone can afford automobiles, shun buses for the most part.

Greater conservation potential does exist in the transportation sector in the longer term. The most promising prospects appear to lie in gradual shifts of urban transport modes toward mass transit, mopeds, scooters, etc., aided by energy-conscious transportation planning and urban design. Urban sprawl is already straining public transportation in many LDC cities, so planning efforts are urgently needed in the next few years if long-term conservation is to remain a viable possibility.

Conservation in the inter-city transport sub-sector will also require long lead times, and is likely to be somewhat capital intensive. Most inter-city passenger travel is by railroad, bus and air. Improving aircraft efficiencies will require many years, since most planes now in use are those manufactured by U.S. and European countries 10-20 years ago, and newer, more fuel-efficient jets now being built will require enormous capital expenditures for purchase by LDC's. Retrofitting aircraft already in use is considered cost-effective in only a few cases, even in the U.S. Load factors are already very high in LDC's, since the limited number of flights ensures that most are full (or even over-booked).

About half of all freight transport in LDC's moves by road, compared with 20 - 40 percent in industrialized countries. Since road transport is second only to air in energy-intensity, and little airborne freight traffic is found in LDC's, the high level of road transport is an important contributor to the highly energy-intensity of LDC freight transportation. The greatest conservation potential here appears to be in mode shifts, although improved vehicle efficiency (especially for trucks) could also make a difference.

Conservation opportunities in inter-city freight transport include replacement of truck fleets with more efficient vehicles (a long-term task), expansion of railroad systems (again, long-term and capital-intensive), and - most important - careful purchase of energy effieicnt systems and vehicles as the transport sector grows. Economics alone may not induce these changes

since fuel costs still represent only a small portion of total transport costs in most countries. Far more information is needed to determine fuel-intensities of different transport systems and needs in different countries, in order to carry out transportation planning with energy-efficiency as a conscious and high-priority goal.

E. ELECTRIC POWER GENERATION

Approximately 16 percent of fossil fuel consumption in the non-OPEC LDC's goes to electric power production, and most of this is oil, which accounts for about half of all energy used to generate electricity. (Forty percent of LDC power comes from primary sources - hydro, nuclear and geothermal - and ten percent from gas, coal and biomass). The electricity sector of LDC's is expected to grow faster than total energy use over the balance of the 20th Century; the World Bank projects nearly 10 percent annual growth in electricity for LDC's between 1976 and 1990. Because industrial use accounts for half of all electricity consumption in LDC's (as opposed to 35 percent in the OECD nations), the growth of electricity will be closely tied to economic growth generally and industrial growth particularly.

The efficiency of thermal power generation is generally lower in developing countries than in industrialized countries, with Korea as a notable exception. Data collected by the World Bank from UN, OECD and oil company sources indicates, for example, that Brazilian fossil fueled power plants require 19 percent more energy input per kwh produced than U.S. plants, and 24 percent more than

French plants. The fuel penalty is still higher in Turkey and India.

Greater efficiency of fuel use for electric power could be achieved in LDC's through a number of means, most of which would require substantial capital investments. Since the electricity sector will require rapid expansions of capacity to meet growing demand, most conservation achievements can be expected to center in these new facilities, rather than in improvements to existing facilities. Among the measures that could be taken are:

(1) optimal economic sizing of generating plants (generally larger than existing plants);

(2) establishment of more extensive interconnections among grids;

(3) achievement of improved load factors through load management and peak load pricing mechanisms;

(4) co-generation of electricity and industrial process steam; and

(5) shifts from oil to other fuels.

Rural electric systems are especially capital-intensive and inefficient due to their remoteness, small base loads, and fuel transport costs. Recent re-examination of rural electrification policies, undertaken by national governments and multilateral lenders in response to escalating capital and fuel costs, appears to be leading toward a shift of emphasis away from rural electrification by central grid and toward smaller decentralized systems. Such systems may employ renewable sources such as photovoltaics.

F. RESIDENTIAL

It has been estimated that household energy use for all the developing countries as a whole constitutes from 50-60 percent of total energy consumption counting both commercial and non-commercial fuels. There is however a wide divergence in the type of fuels used between the advanced LDC's (which favor electricity) and the poorer primary exporters and agricultural economies (which use non-commercial fuels, primarily woodfuels). In the poorer countries, most of this fuel is used for cooking and water heating, for washing dishes and clothes as well as for bathing. The potential for savings of commercial fuel in the residential sector in these countries is almost non-existent because little is consumed to start with. A potential does exist, however, for improving the end-use efficiency of non-commercial fuels, and this area deserves attention because the unconstrained use of wood based fuels (including charcoal) is leading to widespread deforestation and soil erosion in Sahel, Nepal, and elsewhere. In such countries it is important to improve the efficiency of the cooking stoves and charcoal production. The most promising opportunities in this area, however, are for switching to appropriate renewable technologies.

The larger potential for improving energy productivity in the household sector lies in urban residences, especially in the more advanced (and the balanced growth) LDC's. Areas that deserve additional attention include space heating, air

conditioning, lighting and ventilation in buildings. There is a misconception that little energy is used in this sector since most urban centers are in the lower temperate and tropical belts. In fact in some countries considerable amount of commercial energy is used in urban residences, and the potential for efficiency improvements is significant. This is because many developing countries have adopted western-style building codes and designs with little consideration given to their appropriateness in the setting where the structures were being constructed. Multi-family apartment buildings are typically thin-skinned, fail to utilize solar radiation and natural light effectively, have excessive lighting and poorly maintained space conditioning and ventilation systems. In addition, building owners often do not install central air conditioning with the result that tenants use inefficient window units.

Long-term conservation potential in the urban residential sector is found in such areas as energy-conscious building codes (including encouragement of passive solar designs), appliance efficiency, and solar water heating.

G. COMMERCIAL

The opportunities for increasing efficiency in the commercial sector are again in buildings. In the short term, the opportunities are in housekeeping improvements and retrofits of existing buildings. The previously mentioned Kenyan energy survey revealed that electricity consumption for 25 Nairobi hotels dropped 25% between 1977 and 1978, primarily due to housekeeping measures. Similarly, electricity use in a large

government building dropped 18% over the same period. But since construction activity takes place at a rapid pace in the urban centers of the developing world, the larger opportunity is in energy-efficient urban design using natural lighting and shading, less energy-intensive construction materials, (such as brick, adobe and stone).

Widespread use of life-cycle cost analysis in building design would help in the realization of conservation goals for this sector.

H. DETERMINATIVE DEVELOPMENT PATHS

Thus far in this chapter we have discussed ways of providing the same services to a growing economy with less energy. But countries may also benefit by thinking in broader terms about the energy intensity of their economic development plans and asking whether those plans are consistent with the energy situation that they will be facing in the future. Countries that will have to import increasingly expensive oil and coal in the future could reexamine their industrial development objectives and plans and anticipated development of their transportation system to see whether there are less energy intensive developmental paths with equal or greater opportunities for GNP growth, jobs, and benefits that reach the greatest number of people in all economic groups.

Very few other studies have attempted to quantify the role of energy conservation in developing countries. The set of projections prepared by The Energy Research Group of Cambridge University for the World Energy Conference included various degrees of energy

conservation.[51] In the group of projections assuming high economic growth in the LDC's one pair (# 3 and #5) indicates a potential for conservation in addition to that due to normal price effects (described by a price elasticity of -0.3). Active conservation efforts including some shift in development strategy reduced demand in 2000 by 20 percent.

A rethinking of national economic development strategies in light of the energy situation could, particularly in the long term, have a strong effect on LDC energy demand. Although we attribute great importance to this concept in terms of the welfare of individual countries, it is difficult to quantify and we have not assigned an oil savings to such approaches.

V. CONSTRAINTS ON THE IMPLEMENTATION OF RENEWABLE ENERGY AND CONSERVATION STRATEGIES

A. INTRODUCTION

In the previous chapters we have estimated the potential for replacing oil with renewable technologies and more efficient energy utilization processes and equipment. That analysis deliberately ignored the economic, fiscal, legal and organizational requirements associated with the implementation of the large scale programs that would be necessary if anything close to these technical limits are to be achieved. The technical "upper limits" should be viewed as possible goals physically capable of being accomplished within or near the time periods specified. But whether in fact they come even close to being achieved will depend critically on what policies are taken by such actors as the developing country governments, potential donors, development and private banks, energy exporting countries and manufacturers of equipment. Equally important is the set of conditions we posit over the next decade or two regarding the availability of other more conventional energy options to the developing countries such as coal, natural gas, and nuclear power. In what follows we describe each of the various barriers to the introduction of renewable resources and conservation in some detail with a view toward delineating the kinds of actions and programs that would work to ease the transition of developing countries away from their heavy oil dependence.

We discuss the barriers under three headings: Technical, Economic-Financial and Institutional. The relative importance of the various barriers is discussed in the next chapter.

L. TECHNICAL BARRIERS

Technology Development

Considerable differences of opinion exist concerning the extent to which the outputs of RD & D programs in the advanced industrial countries will be utilizable in third world countries. Undoubtedly the tendency of the developed countries has been to fund programs and projects which are associated with central station generation of electricity, large scale industrial manufacturing operations and equipment requiring relatively sophisticated pools of skilled man-power. Less attention has been paid to programs directed toward technological innovation which would apply to medium and small scale operations. Nor has significant interest been shown in developing and demonstrating equipment which is adaptive to the levels of production and managerial skills to be found in developing countries.

This is not due to the potential applicability of the technologies. The applicability of many RD & D achievements with respect to photovoltaic cells, energy storage systems, new methods of building construction, solar assisted cooling, small scale hydro and wind systems and improved efficiency in electric motors, will be almost as great in the third world as in the advanced industrial countries if they are properly adapted. In fact, in some LDC's the conditions for the widespread use of these technologies may be more favorable than in the advanced industrial countries, other things being equal, given the more limited set of conventional energy options and higher energy costs in these countries.

Even so it is clear that if substantially greater efforts to make the renewable and conservation RD & D efforts in the U.S., Europe and Japan more compatible with the requirements of the developing countries, the cost competitiveness and relevance of these

alternatives could increase significantly in a relatively short period. The reason for this is that prices are rising rapidly in the third world for energy in almost all forms. For example, the cost for installed conventional hydroelectric facilities has doubled or tripled in many LDC's since 1973. The cost of oil based electricity supply has gone up even faster. Were these increases to be accompanied by sharp declines in the cost of photovoltaic generated electricity, for example, it could change the whole outlook for onsite generation of electricity within a relatively short period.

Field Information

The ability of the LDC's to accelerate their use of renewable resources and utilize new energy conserving equipment and processes will depend critically not only on the success of research and development efforts, but the extent to which those efforts produce realistic estimates of future costs. Such estimates form one important component of the decision process of governments and the financial community prior to the completion of these RD & D undertakings. Those decisions can take the form of support for medium scale demonstrations and pilot plant scale operations in developing countries and other types of assistance. If these technologies are to fulfill their potential role, much more knowledge has to be generated on the use of a variety of systems in the field. At present little is known about 1) how specific units will operate under field conditions, 2) the requirements for maintaining their performance at satisfactory levels, 3) their operating characteristics compared to competing energy systems and 4) the impacts on other components of the national system of energy supply, distribution and

utilization. The information needed covers the social, fiscal and managerial as well as the technical engineering and cost aspects of these technological interventions.

With few exceptions field demonstrations and studies involving renewables and conservation in the LDC's have yielded only meagre amounts of fiscal and management information even though good data and analysis along these lines must precede decisions by the actors listed above to encourage the usage of such systems on a much expanded scale. The sooner a range of these pre-investment demonstrations and studies are undertaken, the greater influence they will have on current critical deliberations among policy-makers at every level.

C. ECONOMIC AND FINANCIAL BARRIERS

Capital Costs and Rates of Return

A common characteristic of virtually all of the measures discussed in this report is their capital intensity. In general they replace the cost of petroleum as a fuel by a capital investment in equipment to make use of renewable (and often free) resources and to make activities more energy efficient. On the face of it, in a capital short economy, where interest rates, or required rates of return are high, such investments may not appear economical. On the other hand, although these measures may entail large imported components, the oil which they replace is entirely imported. The cost assigned to oil in analyses of such investment decisions should reflect its foreign exchange cost. It is rare, however, that appropriate shadow prices have been used for such decisions.

Production Economics

The costs of many of the technologies referred to in this paper

are a strong function of the scale of production. This, for example, pertains to many solar devices, elements of alcohol fueled internal combustion engines and energy control systems for small scale industry. On the other hand individual developing country markets are small and there is a desire to retain the maximum amount of the production process in country. A major challenge is combining mass production of the elements which have the greatest economies of scale with the maximum use of local labor and fabrication capability.

Uncertainties in the Future Costs and Availabilities of Conventional Energy Fuels

The economic viability of many of the measures discussed in this report depends on prevalence of high world oil prices. A planning and development process which has grown up in an era of cheap oil has difficulty in adapting to a world of $26 a barrel oil. The urgency of many renewable and conservation options, however, derives from the expectation of world oil costing $40, $50 or more a barrel in the future. It is not at all clear what even current prices might produce in the way of a world coal market or in the price and availability of natural gas. Nor is it clear that other mechanisms, such as a two tier pricing system, might not be created by OPEC to help alleviate the balance of payments problems of some or all of the oil importing LDC's. These very large uncertainties are major inhibiting factors, reinforcing the reluctance of many LDC's to make the very large capital investments required to implement renewable and conservation strategies.

The Lack of Financing Arrangements

Over the past year the World Bank as well as a number of other development banks has started to examine the conditions under which they would be prepared to make major investments in renewable

resource technologies and industrial equipment for using energy more efficiently. The very large amounts of capital that will be required if these resources are to replace the use of petroleum products at a significant rate will require major commitments not only from the development banks but also from the export-import and the private banks. Given the past record of the banking community in focussing its energy investments in conventional central station electricity generation and more recently in the exploitation of known fossil fuel reserves, it is not clear under what circumstances the banking community will be prepared to make necessary commitments. Moreover many of the developing countries in which renewables may have the highest technical potential for replacing oil are facing increasingly difficult balance of payment problems as a result of the increase in international oil prices. Finally, risks are increased because, elsewhere, in all but a few cases in the areas of industrial energy conservation, many parameters needed to determine the economic viability of individual projects are unknown.

That interim arrangements exist to lower the risks to the banks is not the issue, the question is the rate at which arrangements will come into play, the levels of commitments that will be made and the conditions borrowers will have to meet. These financing issues lie at the heart of the problem. For example, if the banking community continues to exert pressure on third world countries to move toward marginal cost pricing of energy fuels, this will have a profound influence on the economic competitiveness of these new technologies. Similar effects will be felt by utilities and central banks in the LDC's as a result of the recent decision of the World Bank to support comprehensive energy supply-demand assessments as a

preliminary toward the adoption of energy master plans. Given the problems of financing very large numbers of small scale units (windmills or water heaters or conservation devices) these assessment activities may have to be extended to the development of "packages" of renewable and conservation measures.

D. INSTITUTIONAL AND OTHER FACTORS

Attitudes of LDC Governments towards Renewables and Conservation

The receptivity shown toward renewable energy sources and conservation in the LDC's varies widely. At the World Energy Conference in 1977 a number of third world countries objected strongly to LDC energy demand projections prepared by a Cambridge University group which incorporated various levels of conservation. The objection was based on a confusion between conservation as reduced services (a reduced growth rate in output and services) and conservation as increased efficiency (or increased growth rate for a given energy input). Within individual countries, however, attitudes are changing from one year to another. Not surprisingly the interest among the more advanced developing countries toward industrial energy conservation has increased considerably over the past several years as evidence becomes available from the U.S., Europe and Japan that there are significant energy savings to be achieved in industrial energy use. Considerable attention has also been directed toward renewable energy sources by a few oil importing countries such as Brazil which are amply endowed with the combination of land, soil and climate to grow large amounts of biomass. In some agrarian economies small and medium scale support systems based on renewable resources have been received with favor. By and large, however, the attitudes of key policy-makers in the electric utilities,

central planning ministeries and central banks range from caution to skepticism.

Engineers among these groups complain that demonstrations and pilot operations for most of these innovations have not yet proceeded to the point where they can make recommendations to governments. Central planners are concerned with the prospect of a national renewable energy strategy which would lead to a long term dependence on sources of technological know-how and equipment in the advanced industrial countries - in exchange for their present dependence on OPEC. Finally, central bankers worry about investing in systems without assurance they are both cost-effective and capable of generating a basis for repayment of loans. Contributing to negative attitudes has been the perception in LDC's that low priorities have been assigned to renewables and conservation up to now in the advanced industrial countries. These perceptions have at the very least strengthened the hand of the opposition in many third world countries.

On the other hand, there is some evidence that the price rises of the last quarter of 1979 have had a significant impact on the attitudes towards energy problems in many developing countries. Oil import costs have now reached a level that can not be ignored and some of the factors that mitigated the impacts of the 73-74 price rises (such as increases in world sugar prices and favorable grain harvests) do not prevail. For the most part, however, the increased awareness of the acuity of the energy problem has not yet been translated into strong support for the use of renewable resources and measures to increase energy efficiency.

The Lack of Energy Organizations

To mobilize the capability of a nation and its individuals in a new endeavor requires appropriate institutions. In only a very few of the larger and more advanced LDC's have organizations begun to be formed which can take responsibility for renewables energy sources and conservation. Electric utilities are just beginning to perceive their self-interest in fostering decentralized use of renewables as an alternative to conventional rural electrification, and in encouraging conservation among industrial and residential users. Moreover, the highly subsidized present price structure in almost all LDC's which is heavily embedded in the utility management structure actively discourages increased energy use efficiency and the use of renewables.

The requirements for effecting wide spread use of renewables in medium or small scale industry are substantially different from involvement with large scale major industrial users. In the case of the latter we can expect electric utilities to move quickly to assert their control, once it is assured that the projects under discussion are financially viable. For the former, new organizations will be required and because many of these applications will be in rural areas, these organizations will have to coordinate their activities with those of agriculture and rural development agencies, with all the jurisdictional disputes such coordination entails.

Some LDC's are attempting to circumvent these difficulties by exerting pressures on their electric utilities to take on both rural energy delivery operations and energy conservation audits. Others are organizing energy departments, commission or ministries to oversee all phases of energy supply and demand. In any case it

is evident that a great deal of effort will have to go in to building energy management institutions with expertize in both of these rapidly developing areas.

The Lack of Trained Personnel

The lack of technicians capable of analyzing the renewable and conservation technologies to be employed in specific situations, servicing the equipment to be installed and managing the overall operation in an economically efficient manner, represents a major difficulty in all third world countries in forging ahead with an accelerated program. Few universities in third world countries house faculty with the theoretical, let alone practical, knowledge of these kinds of technological and management operations. A few research institutes in India, Brazil and a few other countries have recognized this deficiency and are moving to train solar and conservation engineers. In a few other countries such as Kenya, Jamaica and Thailand, private companies constructing solar hot water heaters are training individuals who can service their units. But the current level of these activities is negligibly small compared to what is needed.

The resolution of this problem is likely to require considerable lead time and investment in training units within universities and research organizations. In fact the major return on many on-site demonstrations of renewables and conservation equipment may be their educational value in teaching the participants the pre-requisite skills to install and manage such operations on a wide spread basis. Appropriate skills will be most easily acquired for larger scale renewable technologies and conservation practices applied to large scale energy intensive industries such as steel, chemicals and metals fabrication. In such cases not only does expertise already exist

in the advanced industrial countries but the mechanisms of transfer can proceed along conventional lines. But even here the numbers of individuals to be trained over the next five years are likely to exceed the combined resources to be found in the U.S., European and Japanese universities and training groups and knowledgeable private sector organizations will probably have to be employed in such efforts.

Entrepreneurs and Innovators

Eventually the implementation of many of the technologies and strategies discussed in this report will depend on their being adopted by individuals, villages, and industrial organizations of various sizes. This will happen only through the mobilization of an entrepreneurial spirit which may be weak or inhibited in many developing countries. Developing or motivating the entrepreneurial spirit must be carried out carefully, however lest the eventual benefits or renewables and conservation be sacrificed to the short term profit motive. There are examples in both the developing and the developed countries of hastily or cheaply manufactured renewable energy equipment falling apart after a few months and creating a strong negative attitude towards the technology in general.

In a general sense one can argue that economic progress is often driven by the small minority of any population who refuse to simply accept the inadequacies of their lives. As developing countries continue their tentative steps to increased use of renewable energy and augmented conservation efforts, attention should be focussed on those people, institutions and individuals who have identified themselves as having the attitudes and resources needed to undertake change and foster progress, and the psychology needed to seek improvement.

The Lack of Adequate Technology Transfer Mechanisms

The overwhelming investments in renewable resource and energy conservation technologies will be made by governments and the private sector in the advanced industrial countries. This makes it evident that the LDC's will not be able to move ahead quickly in these areas without more effective means of information exchange and technology transfer. Three problems - none of which are new to the area of technology transfer - enter into such a process: 1) the desires of the suppliers of technologies and know-how to limit the transfer to regular commercial arrangements, 2) the aims of the LDC's to control a greater share of the production and distribution of equipment and 3) the deficiencies of existing mechanisms for permitting broader national interest to affect the transfer process. While recognizing that each of these problems involves considerable economic and political complexity it is clear that unless major efforts are undertaken at the national, bilateral and international level, the deficiency of existing technology transfer mechanisms will constitute a significant constraint on the rate of introduction of renewable energy and conservation equipment. In almost all cases we may expect that the more economically developed LDC's will opt for arrangements which allow national control of the production and distribution of equipment as a means not only of fostering import substitution policies, but also as a means to achieve increased security of energy supplies. There are, moreover, in certain cases, considerable benefits to be derived from their acquiring the ability to manufacture equipment in this area for export to other third world countries.

Although no clear policies in these areas have been laid down by industrialized country governments, on-going aggressive

government supported programs by the French, West German and Japanese governments suggest that each is seeking to establish markets for renewables and to a lesser extent conservation technologies along well established commercial lines. The U.S., although it spends considerably more than all of these countries combined on research and development in renewable resource and conservation technologies, has only just begun to initiate LDC oriented commercialization programs. Given the slow entrance of the U.S. into this arena, and the huge body of knowledge it is steadily acquiring, considerable leeway still exists for it to influence the global transfer of technology in these newly emerging areas of energy development.

VI. CURRENT U.S. AND OTHER RENEWABLE AND CONSERVATION ASSISTANCE PROGRAMS

A. SUMMARY

Renewable energy technology development and energy conservation in LDC's are supported in several ways by U.S. Government programs and those of other nations and international organizations. Direct assistance in renewables comes through applied R & D and through construction, development and field-testing of renewable energy hardware. Indirect support is found in programs of basic R&D, institutional development, manpower training, and analysis of energy needs, uses and resources.

In AID, FY 1978-80 programs offering direct assistance in renewables have been roughly divided as follows:

- biomass	$20 million,
of which fuelwood is	12 million
- all other renewables	20 million

These outlays represent less than half of AID's total expenditure on renewables in the 1978-80 period. Approximately $50 million has been devoted to the indirect support activities described above (assessments, training, etc.).

AID has spent only about $1 million on programs to encourage conservation of commercial energy. In addition, a portion of the $12 million expenditure on fuelwood--perhaps $2 million--is used to promote conservation of wood fuels through development

and deployment of more efficient cookstoves and charcoal conversion processes.

DOE's energy activities directed at LDC's are centered primarily in the Department's program of country energy assessments. Completed in two countries and in progress in four more, these assessments have costs just under $8 million in FY 1979 and 80.

B. RENEWABLES: INTRODUCTION

The last few years have witnessed the birth and growth of considerable worldwide activity in the development of renewable energy technologies for developing nations. Programs and projects are now underway in several agencies of the U.S. government, most notably AID and DOE. Multilateral organizations, led by the United Nations and the World Bank, are also carrying out activities in renewable energy. Bilateral aid programs in other OECD nations also include renewable energy components. This section attempts to describe those programs in summary fashion; a more detailed listing, grouped by the technology categories described above, will be found in Appendix B.

Survey Problems

A number of difficulties attend any survey of renewable energy activities. First, not all parties agree on a definition of "renewable energy". This means that the program and budgetary descriptions for different programs may not be strictly comparable. For example, this paper includes mini-hydro projects,

but not large-scale hydroelectric dams, among the renewable energy technologies surveyed, but figures for some agencies fail to make such a distinction. Similarly, some organizations include traditional fuels, such as firewood, in the definition of "renewable", while others refer only to newer non-conventional sources. This paper includes firewood in the renewable category.

Secondly, time lags and differences in available data also present minor problems, particularly for the multilateral and foreign bilateral programs for which up-to-date information is unavailable. Because of rapid growth in renewable energy programs, and current plans for further expansion in the near future, this summary cannot do more than present a rough listing of current programs, along with brief mention of future plans, where known.

Third, many of the programs and projects currently underway are multi-faceted. Not only do they deal with more than one of the renewable technologies, but they also incorporate broader aspects of energy planning and development, such as surveys of current energy use or potential resources, or training in energy policy development. Most programs also reflect larger developmental concerns, such as forestry, watershed management, or agriculture and rural development. Thus it is difficult to break out the dollar amounts devoted specifically to particular renewable technologies.

Finally, the relatively early stage at which most of the renewable energy technologies and programs currently stand means that some projects are only feasibility studies, while others involve actual demonstration and testing of hardware. Research

increasingly includes analyses of the cultural, economic and institutional environment in which a particular renewable technology is to be deployed, and these non-technical factors can be expected in turn to influence the choice and adaptation of renewable energy technologies. This means that it is sometimes difficult to point to specific and "provable" short-term benefits from current programs and projects. Clearly, renewable energy projects in LDCs will necessarily continue to include substantial investments in research and data-gathering components for some time.

The Oil Connection

For the most part, it cannot be said that current renewable energy projects in LDCs are designed primarily for the purpose of displacing current oil consumption, or that they will in fact have such a result. Rather, they are primarily centered in rural areas where consumption of oil (along with other fossil fuels and electricity) is low or even non-existent. Renewable technologies offer hope for relieving pressures on traditional and non-commercial fuels in rural areas, particularly firewood. Yet the oil connection does exist, because rural dwellers are increasingly finding their previously free and abundant wood supplies rendered scarce, inaccessible and prohibitively expensive by the growth of the urban fuelwood market, which itself has blossomed as a result of the rapid and steep increases in kerosene prices in the cities. If city dwellers continue to substitute wood for oil at present

rates, either total deforestation looms in many countries, or new energy sources must be found for the residents of the countryside who have always relied almost exclusively on wood.

Renewable energy programs in rural areas also seek to provide services that have hitherto been unavailable, in order to advance economic development and well-being. A solar-powered irrigation pump, for example, might produce substantial improvements in agricultural yields on acreage not previously irrigated at all. Photovoltaics could provide educational services via television that could have long-term social benefits ranging from increased employment to reduced infant mortality; these are not direct oil-substitution accomplishments, but they do represent a path to economic development progress that is independent of oil and of increased expenditures of scarce foreign exchange and development capital to finance growing oil demands and import needs. As such, they merit serious attention in any program that seeks to aid developing nations with both economic progress and energy self-sufficiency.

Current bilateral and multilateral programs for development of renewable sources of energy are described below, beginning with programs of the United States government.

Agency for International Development (AID)

AID's Renewable Energy Program is funded at approximately $40 million for FY 1980, nearly double the outlays for FY 1978 ($19 million), and nearly 20% higher than FY 1979 ($33 million). AID appears to be at a critical decision point in terms of the extent of future commitment in this area, with further doubling of outlays under consideration.

AID programs in renewable energy are funded through the Office of Energy in the Development Support Bureau (DSB/EY), as well as through each of the Agency's four regional bureaus. Table VI.1 shows funding levels for FY 1980 for each of these bureaus.

TABLE VI.1

AID RENEWABLE ENERGY PROGRAM, FY 1980
($000)

BUREAU	OUTLAY
DSB/EY	8,900
Africa	9,209
Asia	10,008
Near East	4,290
Latin America/ Caribbean	5,102
TOTAL	37,509

The Agency's Development Support Bureau has designated energy as one of several important and functionally cross-cutting programs (others including Women in Development; Science, Technology and Environment; Urban Development and Housing; and Economic and Social Research). Program emphasis for renewable energy sources is described by DSB as follows:

> To increase and better manage energy sources available to the LDCs, special emphasis is placed on renewable energy resources and on decentralizing generation of energy. Energy systems having these characteristics are valuable to the LDC social and economic development plans because they: reduce petroleum consumption costs; provide alternatives to fossil fuels; and employ local technical and managerial skills. Program activities will include assessment of LDCs' energy needs, demonstration and application of new energy technologies, and strengthening U.S. institutions now at work solving LDC energy problems.

The AID renewable energy effort includes both traditional sources (particularly fuelwood) and new technologies (solar, wind, indirect biomass, etc.). For the most part, specific projects within the regional bureaus are components of larger projects dealing with broad areas of rural development. Most projects also incorporate an integrated approach to renewable energy development by including more than one of the renewable technology categories, with technology choices determined by the most pressing needs of the project country and area. The energy program is directed primarily toward low-income countries and rural needs, in keeping with the Agency's overall focus on meeting basic human needs.

AID also funds a number of energy projects and programs that support development of renewable energy technologies indirectly. These include country energy assessments, institutional support for training in technical and policy areas, and data gathering on the structure of energy needs at the village level.

Appendix B lists AID renewable projects, along with those of other U.S., foreign bilateral, and multilateral donors, in groups according to the technology categories identified earlier in this paper.

Department of Energy (DOE)

The Department of Energy's LDC-related energy activities differ from those in AID in that DOE focuses on middle-income countries (including oil exporters) and, for the most part, on technology development and transfer aimed at meeting the commercial energy requirements of developing nations' modern sectors. DOE's efforts generally involve cooperative bilateral agreements, not concessionary assistance. DOE staff reports that DOE's efforts on behalf of LDC's have been hampered by insufficient personnel slots, budgetary commitment and organizational structure within the Department.

Under the policy guidance of the Department of State, DOE manages the International Energy Development Program (IEDP). In this program, DOE conducts comprehensive country-level assessments of energy needs, uses and resources in cooperation with governments of participating developing countries. The assessments are designed to: help the host country develop an improved capability for energy planning; identify means to develop alternative energy strategies; reduce dependence on imported oil; further development of indigenous

resources; and avoid premature or excessive commitments to nuclear power. The assessments usually entail about 10-12 man years of effort plus comparable effort on the part of the participating country over about a one-year period.

Cooperative energy assessment has been completed with Egypt and Peru and are currently underway with Argentina, Portugal and the Republic of Korea. Invitations have been formally extended by the U.S. Government to two additional countries and additional invitations are planned. The program's appropriation amounted to $3.6 million in FY 1978, $3.0 million in FY 1979 and $2.0 million in FY 1980. An appropriation of $1.5 million in Special Foreign currency was also provided.

The Argonne National Laboratory serves as the principal project office for providing energy experts and analytical services to the DOE-LDC assessment teams. The Brookhaven National Laboratory provides the methodological framework for each assessment. A survey of energy-related resources is provided for each assessment by a team of experts from the U.S. Geological Survey.

The Department's renewable activities consist primarily of bilateral technical and cooperative research agreements with a number of countries, technical support provided to AID renewable projects on a reimbursable basis, small efforts in the area of solar commercialization, and a recently-initiated planning effort to establish programs under the broad heading of "International Solar Policy and Strategy".

Specific bilateral agreements in the renewable energy area are listed in Appendix B to this paper, categorized according to the renewable technologies they encompass. The principal efforts involve solar village demonstrations in Saudi Arabia and Mexico. Projects in which DOE has provided assistance to AID are so noted under the AID listings in the same Appendix. The Department's Solar Commercialization efforts, which are intended to provide markets for technology developed and produced in the United States, have consisted thus far of limited surveys of overseas markets; workshops for solar industry representatives, third world researchers, and others; fact-finding missions overseas; and participation in trade fairs sponsored by the Department of Commerce. There would appear to be considerable opportunity to strengthen the DOE solar commercialization program to render it as effective as those of other countries, notably France and Japan.

DOE's International Solar Strategy Task Force has begun drafting goals and priorities for an integrated Departmental approach to promoting solar development abroad, particularly (but not exclusively) in developing countries. Specific programs and projects aimed at realizing these goals remain to be defined by the Department.

DOE has also prepared technical briefings on renewable energy technologies and has provided them to World Bank staff. The briefings describe technologies with potential applications in LDC's, along with their current technical status and the economic outlook for their deployment as substitutes for conventional fuels.

DOE's Office of Solar Energy and Conservation has recently completed and sent to the Congress an International Photovoltaic

Program Plan that focuses largely, but not exclusively, on potential developing country applications of photovoltaic (PV) technologies. Congress requested the Plan in the Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978 (P.L. 95-590). The Plan is designed primarily to further the development of the PV industry in the U.S. by finding and developing sufficient overseas markets (primarily in LDC's) for PV equipment to justify investments in large-scale production facilities that would lower unit costs. Other stated goals of the Plan do, however, include reducing the growth of world oil demand, contributing to the economic and social development of Third World countries, reducing LDC's' oil-related balance-of-payments deficits, and relieving the environmental stresses caused by widespread use of traditional fuels.

DOE's budget for research and development in renewables totals approximately $714 million in FY 1980. Programs in this area are, of course, directed primarily at domestic applications; nonetheless, it is clear that R & D results could in many instance benefit LDC's and other countries. What appears to be lacking is a direct tie-in between these research activities and potential "consumers" in developing countries. A comprehensive periodic assessment of the Department's R & D program, designed specifically to identify points of relevance to LDC needs, might be a starting point for such a tie-in.

DOE's 1980 R & D budget in renewable technologies is summarized in Table VI.2.

Table VI.2

DEPARTMENT OF ENERGY

Renewable Energy Supply R & D Budget Development

	FY 1980 Outlays ($ million)
Solar Applications	125.8
Solar Technology*	381.1
Geothermal	134.0
Biomass	55.8
Mini-Hydro	17.6

*Includes solar thermal power, photovoltaics, wind energy conversion and ocean energy systems.

Source: DOE FY 1980 Congressional Budget Request

World Bank (IBRD/IDA)

The World Bank has very few projects devoted specifically to renewable energy, but a number of projects in agriculture, rural development, forestry, watershed management, electrification and even education include renewable energy components. It is difficult, however, to estimate the fractions of total project costs that are allocated to the energy component.

The World Bank has recently established a Task Force on New and Renewable Sources of Energy. Although IBRD/IDA renewable energy projects are likely to continue to be incorporated into projects with broader purposes, rather than standing by themselves, Bank officials expect renewable components to appear more frequently and prominently in such projects. The Bank normally funds projects of larger scale than village-level renewable technologies, but IBRD staff suggests that ample precedent exists in other rural development-type projects (such as small-scale irrigation) for development of aggregated packages of small renewable energy projects for Bank funding.

Specific World Bank projects are listed in Appendix B.

Inter-American Development Bank (IDB)

The Inter-American Development Bank's energy activities have focused largely on the electricity subsector and on evaluation of fossil fuel resources, and have consumed approximately 25% of the Bank's total lending resources in recent years. Re-

newable technologies--other than hydro-electric facilities (which are mostly large-scale)--have received little assistance from IDB, but are now receiving greater emphasis in plans for future activity.

IDB will spend approximately $2 billion on energy activities between 1979 and 1982, with an unspecified fraction of that going toward development of renewable sources. Most funds will continue to be spent on electricity.

Among the renewable technologies the IDB has stated its willingness to finance are geothermal, solar, biogas and fuelwood. Mini-hydro projects are likely to be financed as components of irrigation projects, as they have been in the past. All these renewable energy activities taken together, however, are likely to comprise only a small portion of total IDB energy-related lending.

United Nations

The activities of the United Nations in the field of renewable energy for LDCs are centered primarily around preparations for the U.N. Conference on New and Renewable Sources of Energy, scheduled for 1981. Preparations for the Conference to date have involved the formation and initial meetings of task forces for each of the technologies to be covered by the Conference. Drafting of technical papers and surveys of needs and ongoing activities are underway within each task force. A task

force exists for each of the technology categories covered by this paper, as well as for certain new-but-not-renewable sources -- oil shale, tar sands and heavy oils.

Nearly all the U.N.-affiliated organizations, such as UNESCO, UNDP, UNEP, INIDO and FAO, are involved to some degree in renewable energy activities. Appendix B lists U.N. renewable energy activities by technology category.

C. CONSERVATION: INTRODUCTION

Energy conservation, defined here as increasing the amount of useful work that can be accomplished with a given amount of energy input, has received very little attention in LDC energy assistance programs. Those efforts that have been undertaken have primarily been directed at improving the efficiency of fuelwood for cooking and other rural uses by introducing improved stoves. Despite evidence that commercial energy sources are used far less efficiently in the developing nations than in the industrialized world, there is very little activity among U.S. programs, and those of multilateral organizations, currently directed toward efficiency improvements.

This lack of assistance activity in conservation is perhaps understandable, due to a number of barriers. A lack of information on how energy is actually used in the end-use sectors of LDCs, and on the energy-intensity of various economic activities, results in an absence of perceived urgency to conserve and of knowledge about how to proceed. Disincentives to conservation are, in many countries, built into the pricing and taxing

mechanisms affecting fuels, electricity and energy-consuming durable goods. Further, LDC governments and private sector entrepreneurs have, in the past, tended to follow the Western model of industrial and general economic development, accepting rapid expansion of oil dependence as a necessary component of GNP growth. Cities with modern air conditioned hotels and office buildings, widening networks of paved highways, and factories using large quantities of electricity and/or fossil fuels for process energy are all part of this model. Industrialized nations have only recently begun to adjust to the changed circumstances that make an energy-intensive economy exceedingly expensive for them; thus LDCs have also been reluctant to recognize that high energy consumption patterns may, in their case, mean drastic reductions in economic growth. LDC public and private officials are now beginning to find themselves having to choose between investments of scarce capital and foreign exchange in energy conservation or in expanded facilities to meet growing markets. Nonetheless, an encouraging trend toward appreciation of conservation needs and benefits has begun to emerge in both donor organizations and recipient nations. The trend may well be strengthened in the 1980's by a worldwide economic slowdown that could diminish market expansion opportunities and put a higher premium on reduced costs.

Agency for International Development (AID)

AID's conservation activities have, for the most part, centered around fuelwood conservation through development of more efficient cookstoves and improvements in charcoal conversion technologies. The African Bureau has been the leading actor in these projects, which are described in Appendix B.

AID's Office of Energy (DSB/EY) has recently initiated a more comprehensive project to promote energy conservation in LDCs. Funded at $500,000 in FY 80, the Energy Efficiency and Conservation project will focus primarily on industry and buildings. Initial targets will be the energy-intensive industries such as cement and brick works, fertilizer plants, power generation, oil refining and primary metals. (See Appendix B). DOE and the National Laboratories will be involved.

AID's Latin American/Caribbean Bureau has initiated a conservation project in the Dominican Republic aimed at the sugar industry.

Department of Energy (DOE)

The Department of Energy has not undertaken any conservation programs specifically aimed at LDC's, although the Department's domestic activities in the conservation area clearly include strategies that could be applicable to the modern industrial, commercial, transportation and urban residential sectors of LDC's as well as to the U.S. DOE's future role may therefore center primarily around the transfer of these conservation technologies and strategies to LDC's.

The DOE Conservation Program budget totals nearly $800 million in FY 1980; of that, approximately $300 million is earmarked for conservation technology development, $60 million for industrial conservation, and $117 million for transportation conservation. The U.S. shares information on its conservation programs with other countries, primarily through the International Energy Agency of the OECD. There is no mechanism, however, for similar exchanges of information with LDC's.

The Country Assessments undertaken by DOE have included examination of the potential role of conservation in meeting projected levels of demand.

VII. CONCLUSIONS OF THE ANALYSIS

Even based on our brief and preliminary analysis some striking features emerge regarding the major issues addressed in this paper: the significance of renewable resources and conservation strategies in affecting world oil demand; and the significance of such strategies in affecting the oil import problems of specific countries.

A. WORLD OIL DEMANDS AND THE NON-OPEC LDC's

While most renewable resource technologies, and strategies based upon them, can have only very modest impacts by the year 2000, in the aggregate they can reduce LDC oil consumption by 8-15 percent by 2000 (see Table VII.1. below). This represents a reduction of world oil demand of 1.5-4 million barrels per day. The large

TABLE VII.1

RELATIVE SCALE OF IMPACT OF RENEWABLE ENERGY AND CONSERVATION STRATEGIES

Type of Program	Reduction of LDC Oil Demand (Percent)
Solar, Wind, Geothermal, etc.	5 - 10
Biomass	2.5 - 5.5
Conservation	10 - 20

range of uncertainty in our estimate derives from two factors: the uncertainty in the rate at which individual renewable resource options and conservation measures will be implemented and the rate of future energy growth in the LDC's. We have translated our calculated percentage reduction in LDC oil demand into absolute terms by using a range of 20 - 25 million barrels per day as the projected non-OPEC LDC oil demand in 2000.

Conservation measures are potentially even more effective than renewable resource programs. In addition to the savings that are apt to come about simply through price effects, based on conservative estimates an additional 2 - 5 million barrels of oil per day can be saved through vigorous energy efficiency programs.

Oil consumption in the LDC's is very unevenly distributed. Only 8 countries account for over 60 percent of total consumption. These countries are (see Chapter II):

Brazil	Argentina
Spain	Korea
Mexico	Yugoslavia
India	Taiwan

Thus, if affecting world oil supply is viewed as a principal focus of U.S. energy assistance, renewable resource and conservation efforts can be directed to a relatively small number of countries.* Since these countries tend to be the more industrialized, a selected

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*/ We do not mean to imply that the countries listed above should be the countries included in such a program. Many other criteria would affect such a choice.

set of options can also be pursued. Of particular importance would be industrial and transportation energy consumption, solar industrial process heat and liquid fuels from biomass.

B. NATIONAL OIL SUPPLY

Quite a different picture emerges if one's primary concern is the oil import problems of individual countries. Many of the developing countries with the most severe oil import problems (as measured by the fraction of export earnings devoted to purchasing oil) fall in the agricultural categories discussed in Chapter II or in the World Bank's lowest income groups. As a group, however, the 45 countries in the agricultural categories account for less than 2 percent of world oil demand. Furthermore, depending on their energy use patterns and resource endowments, there will be large variations in the type of renewable resource or conservation strategy that will be appropriate for individual countries.

Thus programs directed toward the objective of reducing oil import problems will have a very difficult character than those directed towards world oil supply problems. These programs would have to be constructed on the basis of comprehensive national energy assessments combined with evaluations of generic programmatic needs.

C. THE RELATIONSHIP BETWEEN THE NATIONAL AND GLOBAL OIL ISSUES

We have discussed two basic issues, world oil supply-demand balances and national oil import problems as separate bases for

U.S. energy assistance to developing countries. From a policy perspective there is an important relationship between the two which affect their operational priority.

A concern with levels of world oil supply and demand as a criterion for U.S. assistance policy has inherent problems of credibility. The question of "what actions on the part of developing countries can free oil for the world market - and thus for U.S. consumption?" inevitably induces the following question among representatives of the Third World: "What actions on the part of the United States can free oil for the world market - and thus for consumption in the developing countries?" Objectively it is hard to argue that the former question is more relevant than the latter if only for the reason that imports of oil in the U.S. are greater than the total oil consumption of some 80 developing countries put together and much of that oil is being used in the U.S. in ways quite remote from basic human needs.

The development of a U.S. energy assistance program focused on oil must be sensitive to this issue. The success of such a program will depend on its being based on an understanding of and a concern for the national energy problems of individual developing countries. Thus, of the two generic oil issues addressed in this paper, the oil import problem of individual countries should take operational precedence over a concern with world oil balances.

D. THE SHORT, MEDIUM AND LONG TERM ISSUES

The severity and immediacy of the oil import problems of developing countries forces one to seek immediate solutions. Although over the longer term renewable energy strategies and incremental conservation strategies may have comparable impacts, only the conservation strategies can make a difference in the near term. But it would be a mistake to construe the oil problem in LDC's (or the world oil supply problem) as short term. The severe constraints that are generally expected to be created in world oil supplies before the end of the century are likely to create much more severe economic and supply problems for the developing world (and for the Western world) than have occurred to date. The basic challenge to national energy strategy and to assistance policy is to support a transition to the "post-petroleum" era.

In this light, the fact that many of the renewable resource strategies that are available to developing countries do not have large short term impacts does not mean that they are not worth supporting. Indeed, because of the acuteness of their immediate energy problems, most oil-importing developing countries are forced to concentrate attention on their immediate micro-economic and macroeconomic energy problems. Their time horizons are necessarily very short. It is incumbent on an energy assistance program to complement a concern for severe short term problems with attention to the equally severe energy problems that will confront countries in the longer term.

E. RENEWABLES - CONSERVATION VS. CONVENTIONAL FUEL DEVELOPMENT

Energy strategies emphasizing renewable resource development and increased energy efficiency can be contrasted with strategies emphasizing the exploration and exploitation of conventional fuels - oil, natural gas and coal. Although these strategies should be viewed as complementary, they often compete for investment funding and the attention of national institutions and assistance agencies. Conventional fuel development strategies offer the possibility to developing countries of substituting indigenous fuels for imported oil in a relatively short period (although longer than for conservation measures). They are also more compatible with the supply enhancement attitudes to be found in most existing energy organizations in developing countries.

A shortcoming of conventional resource development strategies should also be mentioned. In some national conditions increasing the indigenous supply of oil or gas could encourage the further development of a petroleum based energy infrastructure which would become a more and more difficult burden as world and national supplies dwindle. A temporarily increased supply can induce a permanently increased demand and make the eventual need to shift from an oil-based economy more difficult and expensive. Conservation or renewable resource strategies, on the other hand, tend to move countries in the direction of lesser oil dependence, more consistent with longer term trends in the global energy outlook.

This contrast does not necessarily argue against conventional resource development programs in countries where major resources exist. It does suggest, however, that in implementing such programs, consideration should be given to longer-term implications and that those programs be complemented by forward-looking oil substitution programs.

F. THE NEED FOR ENERGY CONSERVATION ASSISTANCE PROGRAMS

If reduced oil consumption is to be an important U.S. assistance objective, the virtually complete lack of activity in the area of increased energy efficiency, or conservation must be corrected. The lack of any significant assistance in this area might be excused if any other assistance agency (national or international) had significant programs in the area. Since that is not the case, a serious evaluation of a U.S. assistance program aimed at increased energy efficiency is called for.

G. THE IMPORTANCE OF NON-TECHNICAL CONSTRAINTS

Energy assistance activities are often thought of primarily in terms of technical research and development, demonstration of hardware and training in various technical and analytical skills. The discussion of Chapter V indicates that despite the reality of technical constraints to the realization of renewable and

conservation strategies, constraints and barriers of a non-technical nature will be more limiting and certainly more difficult to overcome. Attitudes of government planners, the incentive structure of private industry, the lack of a foreign policy element in technology development, and the inadequacy of financing mechanisms for such programs are examples of the barriers which have to be overcome if these programs are going to fulfill their potential.

VIII. POLICY AND PROGRAM INITIATVES

A. INTRODUCTION

On the basis of the analysis summarized above a number of policy and programmatic initiatives can be identified. These suggestions must be qualified in a number of ways, however. First, because of the broad scope of our analysis (and the very limited time available to carry it out) any programmatic recommendations must be general in nature. If the general conclusions summarized in the previous chapter are accepted, a concerted effort should be made to identify more specific programmatic initiatives. These should derive from a clear definition of U.S. policy interests in the developing countries complemented by analyses of individual country needs and opportunities. Second, the exclusive focus on oil limits the completeness, if not the strength of our recommendations. Finally, even where oil is concerned, we have not attempted to determine whether expenditures to free more oil through these kinds of programs in LDC's are as cost-effective as domestic programs with the same objective.

Nevertheless, in view of the general importance and seriousness of the LDC oil import problem, these recommendations can be made with some confidence and, indeed with some urgency. They are presented under the same headings used to analyze constraints on the implementation of renewable resource and conservation strategies: Technical; Economic and Financial; and Institutional. These are followed by broader policy recommendations.

B. TECHNICAL PROGRAMS

Research and Development

A major effort should be undertaken to develop renewable energy and conservation technologies which are relevant to the needs of developing countries. In some cases relatively small changes in research programs (or modest extensions of those programs) can yield useful products - and products with international marketing potential.

A starting point could be a detailed evaluation of DOE's renewable energy RD & D program to determine the areas with greatest potential for application in LDC environments. This evaluation should be carried out jointly by U.S. and developing country energy experts, and should be updated periodically. Consideration should be given to creation of a distinct budget item (or items) for developing country energy technology, and to establishment of a permanent advisory body to review DOE's renewable RD & D activities for relevance to LDC needs and priorities. DOE's existing framework for international activities should be built upon. The Solar Energy Research Institute has some familiarity and experience with international programs. A more detailed set of programmatic recommendations in this area is contained in a report prepared for the Domestic Policy Review of Solar Energy.[52/]

A parallel effort should evaluate research and development in the private sector. In addition to identifying developments of relevance to LDC's the study should evaluate ways in which information can be gathered, analyzed and disseminated to private firms on the potential market for energy technologies in LDC's

These various studies should recognize the limited number of qualified personnel in this country in these areas and the importance of maintaining high standards in our assistance efforts. Programs should be identified which can increase, by supplementary training, the availability and quality of qualified U S. experts in pertinent technical fields.

Field Tests

A number of bilateral or multilateral programs should be established to erect and field test a range of renewable energy technologies and selected energy conservation technologies in a variety of developing country conditions. The large number of countries of concern means that each test should be carried out in a manner that allows transfer of the results to other economic and geographical conditions. Such field tests should employ a standardized evaluation procedure which addresses system reliability and maintainability, system economics relative to currently available energy options, energy supply/distribution implications, and other factors. Mechanisms (bilateral or multilateral) need to be developed to disseminate the results of these field tests to LDC research, planning and policy groups. It is important to provide not only the actual test results but also information which allows other countries to interpret those results for their own conditions.

Information Exchange

The requirements of information exchange are much broader than the need to disseminate the results of field tests. Multiple avenues need to be developed to obtain wide distribution of information

on energy survey and analytical methods, technology characteristics, current R & D programs, demonstration experience, environmental implications, the availability of equipment from manufacturers and projected costs and characteristics. Although meetings and workshops can contribute to this effort, a more continuous structure of responsive information centers or clearinghouses is required to satisfy fully the needs in this area.

C. ECONOMIC AND FINANCIAL PROGRAMS

Financial Incentives

In order to promote investment by developing countries and the private sector in renewable energy systems and in enhanced energy efficiency, mechanisms should be established to offer low interest loans, loan guarantees, or other capital subsidies or risk reduction measures. Ideally, such measures should be tied to the price of world oil sc that the subsidy declines as oil prices rise.

Lending Policy

The criteria and priorities for U.S. loans and grants should be modified and the U.S. should bring its influence to bear on the policies of international lending institutions of which it is a member to augment substantially the commitment to investments in (a) energy efficiency improvements, (b) biomass, and (c) other renewable energy systems. Priorities should be changed in a similar way for international insuring organizations(especially OPIC). In the aggregate, such agencies are unlikely to be able tc underwrite the total investment required for all such systems. The emphasis should be on facilitating private sector investment in energy efficiency improvements and currently economic biomass

and other renewables projects, by 1) providing improved access to OPIC risk reducing schemes, 2) partially subsidizing high-visibility private sector demonstration-type projects currently only marginally economic, through means such as more ready access to financing or to International Finance Corporation syndications; and 3) devoting limited grant monies to public or private sector projects which could not currently be considered likely to be economic but which are important as means of demonstrating promising technologies, institutional arrangements (e.g. small holder firewood projects), or other aspects.

Financing of Multiple Unit Projects

Existing financing mechanisms should be strengthened in agencies such as those cited above to augment their ability to provide loans or grants to or insurance coverage for multiple small-scale projects, the size of any one of which would be too small to warrant consideration under those agencies' normal project size criteria. Models for funding such smaller projects include funding through LDC development banks or funding of a single investor/project sponsor to undertake multiple projects (e.g. installation of 100-500 village renewable energy systems) in a given country or region.

Direct Purchase

The DOE direct purchase program (currently limited to comparatively small quantities of solar collectors) should be expanded to other components or complete systems for installation and testing as demonstration units in developing countries.

D. INSTITUTIONAL ISSUES

Addressing the Perception Problem

Of the many constraints to the implementation of renewable and conservation strategies identified in Chapter V, one of the most fundamental is the perception on the part of LDC governments and some financing institutions that such approaches are of limited utility, uneconomic, or developmentally retrogressive. The U.S. should provide LDC energy planners with information and analyses that will foster greater awareness of the potential role of renewable technologies. Broad scale analysis should be carried out by groups of developing country analysts of the economic, technical and institutional aspects of renewable resource utilization in the context of economic and social development. These can be supported by U.S. technical assistance but should not be U.S. efforts.

The UN Conference on New and Renewable Sources of Energy will provide an excellent opportunity to affect third world perceptions in this area and should receive strong U.S. support. In preparation for the conference, and in anticipating follow-on activities, the need for technical-economic assessment in a national developmental context (and not just technology or research description) should be emphasized.

The U.S. Example

The value of the U.S. example in energy conservation and renewable resources should not be underemphasized in terms of its effect on third world decision makers. U.S. policies and, more importantly, the actual behavior of U.S. industrial and other energy consumers will have a direct bearing on the success

of renewable and conservation efforts in the LDC's and, in particular, on the success of U.S. assistance programs in these areas.

Despite the slow pace of many domestic energy programs, there are a number of positive examples which could profitably be publicized abroad. Primary among these are successes in industrial energy conservation efforts and the diverse efforts of inventors and entrepreneurs in creating a varied and vigorous energy business in the U.S.

Energy Assessments and Institutional Support

The U.S. should continue to provide technical assistance to LDC's in conducting national energy assessments in which the roles of renewable resources and conservation measures can be demonstrated. More attention needs to be paid in these assessments, however, to the development of continuing national energy analysis capabilities and effective institutions to plan and carryout energy programs. Such assistance should include the development of a capability to collect and analyze energy information, training of national energy organization personnel (both formal training and on-the-job training in the context of the national energy assessment and other joint projects); and assistance in establishing a network (e.g. an extension service) to provide planning and implementation support to regions or villages.[53/] It also would be useful to encourage interaction among such national energy organizations through support, for example, of international or regional symposia and joint training/workshop sessions in the U.S.

Training

There are important needs for training at many levels. Training in national energy planning and assessment methods as carried out for example by the AID Energy Management Training Program is very important but addresses only the most macroscopic level. A further critical long-term need is the training of field personnel necessary for on-site energy audits and assessments, system maintenance, etc. Most expertise of this type appears to reside in the private sector, but it is not yet clear what role the public and private sectors should play nor how such private sector training could be mobilized. One promising option would be to incorporate in loans for installation of multiple systems liberal provisions for manpower training, maintenance, etc. Another option would be to fund national energy organizations to build up such expertise. This area should be studied further, in conjunction with private sector experts particularly regarding the shortage of U.S. technical personnel with pertinent training and experience in this area.

Technology Transfer

A better understanding is required of the possible means of accelerating the transfer of key renewable energy and conservation technologies from the private sector to developing countries on terms which promote their implementation. An evaluation of this problem should include the issue of the identification of opportunities by the private sector and incentives required to overcome licensing barriers. The present uncertain fate of the proposed Institute for Scientific and Technological Cooperation

makes it impossible to judge whether such an institution could play the important role of representing foreign policy interests in technology development.

The U.S. government should support multiple avenues - including but not limited to the DOE/Commerce Department technology transfer program, the planned AID/VITA technology transfer program, and university-oriented programs - to promote transfer of technical and economic information on renewable energy systems and energy efficiency improvement to developing countries. The U.S. also should support emerging information exchange and technology transfer programs among the developing countries themselves. An important component of such technology transfer programs should be the exchange of information and evaluation of actual field experience in the developing countries.

As discussed above, the United Nations Conference on New and Renewable Sources of Energy will provide a useful forum for information exchange and a means to bring about a more positive view towards renewable energy in LDC's. A subsidiary goal should be to strengthen the concept of increased energy efficiency as a complement to renewable resource programs. In such a forum, however, it is unreasonable to expect that the discussion will focus on purely technical issues. Indeed, given the importance of the non-technical constraints on the implementation of renewable resource strategies discussed in this report, it would be a disservice to the LDC's to focus only on technical issues as though they were the major ones of concern.

E. POLICY INITIATIVES

Development of Assistance Policy

The examination of the single concern of oil supplies as one basis for U.S. energy assistance has served to underline the urgent need for a clear definition of U.S. energy assistance policy. Various bases for such a policy - meeting basic human needs, nuclear non-proliferation and world oil supply - are more or less operational in current programs but those bases are neither complete nor without internal conflict. The development of a coherent energy assistance policy should be based not only on a clear identification of the full range of U.S. policy interests but also a clear perception of the nature of the energy problems confronting the developing countries, and potential solutions to those problems.

An Energy Efficiency Initiative

The U.S. should design, in collaboration with developing country governments, a major new initiative to increase the efficiency with which energy is used in developing countries in support of their economic and social development goals. Such a program should be approached with sensitivity to the perceptual problems discussed in this paper. It could be carried out in concert with other developed countries but should begin by efforts which would clearly demonstrate the developmental benefits of increased energy efficiency. One approach to such an initiative would be to carry out a pilot program in one or more countries (carefully chosen) to assemble, find financing for, and support the implementation of a national energy efficiency effort.

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19. Ram Kumar Chopra, "Energy: Outlook and Issues" Background Paper prepared for the World Development Report (Discussion Draft - March 1979); World Bank. See also A. Lambertini, "Energy Usage in Developing Countries", Internal Draft, World Bank - January 1979.

20. James W. Howe and James J. Tarrant, "Assistance to the Third World on Urban Energy" Overseas Development Council, Washington, D.C., January 1980.

21. This discussion draws heavily on a paper by Bill Knowland and Carol Ulinski (Reference 5). Traditional fuels are often referred to as noncommercial fuels but as wood, charcoal and other traditional fuels enter the market, increasingly that term becomes a misnomer.

22. "Adrian Sommer, cited in Erik Eckholm, Planting for the Future: Forestry for Human Needs, Worldwatch Paper 26, Worldwatch Institute, Washington, D.C. - 1979.

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28. J. Parikh, and K. Parikh, "Mobilization and Impacts on Biogas Technologies," Energy, 1977, Volume 2.

29. P. Ghate, "Biogas : A Pilot Project to Investigate a Decentralised Energy System," State Planning Institute, U.P., Lucknow.

30. U.S. Department of Energy, "Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment" Washington, D.C., 1979.

31. U.S. Department of Energy, "Joint Peru/United States Report on Peru/United States Cooperative Energy Assessment", Washington DC, Aug. 1979. See also Reference 30.

32. This estimate is based on U.S. light industry, considered to be representative of LDC industrial mix.

33. Reference 30, annex 8.

34. The practical feasibility of wind machines is very sensitive to these factors because of the fact that power output depends on the cube of the wind velocity. Thus, the difference between a site with a steady wind speed of 8 MPH and one with a wind speed of 10 MPH is a factor of 2 in power output.

35. T. Turner, "Appropriate Technology for Small Energy Supply in Developing Countries" in Appropriate Industrial Technology for Energy for Rural Requirements UNIDO, United Nations, N.Y., 1979. See Annex A and B for descriptions of wind machines.

36. See, for example, Overseas Development Council, "Energy for the Villages of Africa", Washington, D.C. 1977.

37. P. Teagan, "Potential Use of Solar/Wind Resource in Peru", Annex 7 in Reference 31.

38. J. Poland, et. al., "Wind Energy Assessment for the Commonwealth of Puerto Rico", General Electric Co., October 1979.

39. Vaclav Smil, "Intermediate Energy Technology in China," Bulletin of the Atomic Scientist, February, 1977, pp. 25-31. See also J. Howe, et. al., "Energy for Developing Countries", op. cit. and N. Brown, Ed. Energy for Rural Development, op. cit.

40. See, in addition to the previous references, A.E. Chittenden, et. al., op. cit.

41. Eric J. Jeffs. "The Application Potential of Hydro Power," Energy 4, 5 pp. 841-849, October, 1979.

42. U.N. Department of Economic and Social Affairs, New Sources of Energy and Economic Development, 1957.

43. U.N. ECOSOC Committee on National Resources, Status of the Use of Geothermal Energy and Rutuse Prospects for Developing Countries, Pub. '77.

44. Average costs in the Philippines are now stated to be $900/kw. Even experiments with lower temperature systems by the Magma Power Co. in California indicate costs of $1,500/kw for such systems.

45. Energy/Development International and the MITRE Corporation , "Energy Development in Central America" Report in preparation for USAID, Washington, D.C., January 1980.

46. Personal Communication from Robert Ichord, USAID.

47. P. L. Auer, et. al., Unconventional Energy Resources, World Energy Conference, August 1977.

48. Previous reports which have discussed energy conservation as an important area for LDC attention include R. Thomas Hoffman and Gregory A. Thomas, "United States Policies and Programs for Promoting Energy Development in Less Developed Countries: Survey and Recommendations" Report to the Office of Technology Assessment, U.S. Congress, Nov. 1979; D. G. Fallen-Bailey and Trevor Byer op. cit, (Reference 2) and James W. Howe and James H. Tarrant, op. cit (Reference 20).

49. The discussions of conservation potential in the industrial, transportation and electricity sectors within this chapter draw heavily on three unpublished World Bank staff papers. Where the text refers to "World Bank figures" or similar terms, the sources are:

    Ram Kumar Chopra, "Energy: Outlook and Issues", Background Paper to the World Development Report, 1979, March 1979.

    B. J. Choe, "Demand for Energy and Electricity in Developing Countries: An Aggregate Approach", January 1979.

    A. Lambertini, "Energy Usage in Developing Countries", January 1979.

50. Energy Users News, April 2, 1979 as quoted by Roger W. Sant, "The Least Cost Energy Strategy", Mellon Institute, Arlington, Va., 1979.

51. I. J. Bloodworth, et al, op. cit. (Reference 18).

52. Domestic Policy Review International Panel, "Policy Options", July 26, 1978.

53. For a series of recommendations on assistance in energy information gathering see the proceedings of the National Academy of Sciences International Workshop on Energy Survey Methodologies, held January 1980. Report in preparation.

APPENDIX A

ENERGY BALANCES FOR SELECTED COUNTRIES

INDONESIA

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1973
(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	126.	-	-	6.8	1040.	1172.8
Industry	62.	36.	-	2.2	-	100.2
Transportation	149.6	-	-	-	-	149.6
Agriculture	-	-	-	-	-	-
Electricity Generation	28.4	0.2	20.	(9.)	-	39.6
Total Resource Consumption	366.	36.2	20.	-	1040.	1462.2

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 86.7

% of oil consumption in total energy used for electricity generation 58.4

Source: V. Mubayi et al, "Preliminary Analysis of Energy Supply and Demand in Indonesia", Brookhaven National Laboratory, Upton, N.Y.

EGYPT

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1975

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	122.	-	-	7.5	216.5	346.
Industry	67.1	43.7	-	19.3	-	130.1
Transportation	64.8	-	-	-	-	64.8
Agriculture	15.4	-	-	2.4	-	17.8
Electricity Generation	46.9	-	78.	(29.2)	-	95.7
Total Resource Consumption	316.2	43.7	78.	-	216.5	654.4

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 72.2

% of oil consumption in total energy used for electricity generation 37.6

Source: U.S. Department of Energy, "Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment", Washington, D.C. - 1979.

PERU

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1976

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	33.6	-	-	9.4	162.	205.
Industry	72.8	27.2	-	14.8	8.7	123.5
Transportation	117.3	-	-	-	-	117.3
Agriculture	8.4	-	-	1.1	-	9.5
Electricity Generation	23.8	4.2	70.	(25.3)	-	72.7
Total Resource Consumption	255.9	31.4	70.	-	170.7	528.

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 71.6

% of oil consumption in total energy used for electricity generation 24.3

Source: U.S. Department of Energy, "Joint Peru/United States Report on Peru/United States Cooperative Energy Assessment", Washington D.C., August 1979.

PAKISTAN

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1974

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	46.4	7.3	-	4.8	329.	387.5
Industry	9.6	118.	-	11.2	-	138.8
Transportation	79.8	-	-	-	-	79.8
Agriculture	10.8	-	-	4.1	-	14.9
Electricity Generation	8.9	51.4	59.*	(20.1)	-	99.2
Total Resource Consumption	155.5	176.7	59.	-	329.	720.2

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 39.7

% of oil consumption in total energy used for electricity generation 7.5

Source: Brookhaven National Laboratory, "Preliminary Analysis of Energy Supply and Demand in Pakistan", Brookhaven National Laboratory, Upton, N.Y.

THAILAND

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1976

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	30.6	-	-	11.0	446.7	488.3
Industry	75.9	3.6	-	20.0	37.3	136.8
Transportation	166.9	-	-	-	-	166.9
Agriculture	40.2	-	-	0.1	-	40.3
Electricity Generation	59.5	7.	47.2	(31.1)	-	82.6
Total Resource Consumption	373.1	10.6	47.2	-	484.	914.9

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 86.6

% of oil consumption in total energy used for electricity generation 52.3

Source: V. Mubayi et al, "Preliminary Analysis of Energy Supply and Demand in Thailand", Brookhaven National Laboratory, Upton, N.Y.

INDIA

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1972

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	154.	80.	-	32.	2920.	3186.
Industry	278.	638.	-	121.	312.	1349.
Transportation	360.	304.	-	6.	-	670.
Agriculture	48.	-	-	17.	-	65.
Electricity Generation	72.	389.	378. *	(176.)	-	663.
Total Resource Consumption	912.	1411.	378.	-	3232.	5933.

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 33.8

% of oil consumption in total energy used for electricity generation 8.6

Source: Government of India, "Fuel Policy Committee Report", 1974

SUDAN

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1975
(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	4.1	-	-	1.1	252.4	257.6
Industry	5.4	-	-	1.3	2.4	9.1
Transportation	20.7	-	-	-	-	20.7
Agriculture	7.2	-	-	0.3	-	7.5
Electricity Generation	3.3	-	5.3	(2.7)	-	5.9
Total Resource Consumption	40.7	-	5.3	-	254.8	300.8

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 88.5

% of oil consumption in total energy used for electricity generation 38.4

Source: O. M. Abayazid, "Energy in the Sudan", National Council for Research, Sudan.

DOMINICAN REPUBLIC

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1977
(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	4.8	-	-	3.5	13.4	21.7
Industry	31.3	-	-	2.1	26.6	60.0
Transportation	18.5	-	-	-	-	18.5
Agriculture	1.6	-	-	-	-	1.6
Electricity Generation	26.5	-	2.8	(5.6)	-	23.7
Total Resource Consumption	82.7	-	2.8	-	40.	125.5

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 96.7

% of oil consumption in total energy used for electricity generation 90.5

Source: V. Mubayi et al, "Preliminary Analysis of Energy Supply and Demand in Dominican Republic", Brookhaven National Laboratory, Upton, N.Y.

TURKEY

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1975

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	105.9	36.2	-	15.2	257	414.3
Industry	102.6	39.1	-	40.1	-	181.8
Transportation	216.5	21.4	-	0.6	-	238.5
Agriculture	42.2	-	-	0.2	-	42.4
Electricity Generation	61.5	44.2	70.0	(56.1)	-	119.6
Total Resource Consumption	528.7	140.9	70.0	-	257	996.6

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 71.5

% of oil consumption in total energy used for electricity generation 35.0

Source: A. Ezzatti et al, "Preliminary Analysis of Energy Supply and Demand in Turkey", Brookhaven National Laboratory, Upton, N.Y.

KOREA

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1973

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Use
Residential-Commercial	53.3	305.1	-	124.2	147.7	630.3
Industry	206.1	37.7	-	55.8	16.4	316.
Transportation	143.6	0.8	-	-	-	144.4
Agriculture	8.	-	-	0.4	-	8.4
Electricity Generation	183.	15.2	421	(180.4)	-	438.8
Total Resource Consumption	594.	358.8	421	-	164.1	1537.9

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 43.2

% of oil consumption in total energy used for electricity generation 29.6

Source: Brookhaven National Laboratory, "Draft Preliminiary Analysis of Energy Supply and Demand in Korea", Brookhaven National Laboratory, Upton, N.Y.

VENEZUELA

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1975

(10^{15} JOULES)

	Oil	Gas & Coal	Hydro*	Electricity	Non-** Commercial	Total Direct Us
Residential-Commercial	43.0	15.5	-	30.2	-	88.7
Industry	86.0	382.2	-	26.7	-	494.9
Transportation	290.0	-	-	-	-	290.0
Agriculture	0.1	-	-	0.2	-	0.3
Electricity Generation	34.8	43.1	30.0	(57.1)	-	50.8
Total Resource Consumption	453.9	440.8	30.0	-	-	924.7

* Taken as fossil fuel equivalent

** Crop residues, fuelwood, charcoal, dung.

% of oil consumption in total commercial energy consumption 49.1

% of oil consumption in total energy used for electricity generation 32.3

Source: Glen Mitchell et al, "Draft of A Preliminary Analysis of Energy Supply and Consumption in Venezuela", Brookhaven National Laboratory, Upton, N.Y.

APPENDIX B

U.S. AND OTHER PROJECTS IN RENEWABLES AND CONSERVATION

BIOMASS/FUELWOOD

AID Africa Bureau	These country projects include components for production and/or conservation of fuelwood and/or charcoal: Africare Forestry Burundi Agricultural Land Protection Chad Reforestation Gambia Forestry Guines Woodlots Mali Firewood Conservation & Production Mauritania Renewable Resources Management Mauritania Firewood/Reforestation Mauritania Reforestation Niamey Department Development Niger Forestry & Land-Use Planning Senegal Fuelwood Production Upper Volta Forestry Education & Development
AID/Asia Bureau Nepal	FY 80 - $720,000 component of Rural Energy Area Development Project
AID/Asia Bureau Sri Lanka	Wood plantation subproject of proposed FY 80 $2 mm Reforestation and Watershed Management Project (Mahaweli irrigation & rural development scheme).
AID/Latin American Bureau Ecuador	Forestry Natural Resources & Environment project planned for FY 1981 is expected to include fuelwood production & conservation component.
AID/Latin American Bureau Haiti	Fuelwood-related efforts (community woodlots, improved charcoal processes, etc.) included in 3 projects: 1) Appropriate Technology, 2) Renewable Energy Plantation, and 3) Wood-Based Fuel Production.

BIOMASS/FUELWOOD

AID/Latin American Bureau ROCAP Project (Central America)	AID's Regional Office of Central American Programs (ROCAP) Woodfuel Alternatives project includes plantation to grow fast-growing tree species for fuel, development of more efficient woodstoves and more efficient wood-burning kilns and furnaces for charcoal production and light industrial uses. Total project cost for FY 1979 & 1980: $1.7 mm.

BIOMASS

AID/Africa Bureau Burundi	Pilot project assisting Barundi government in development of peat reserves and encouragement of peat use by peasants as substitute for rapidly-declining fuelwood supplies. Implemented by Catholic Relief Service. Follow-up project may involve collaboration with government of Ireland.
AID/Africa Bureau Cape Verde	Component of Cape Verde Renewable Energy project will include installation and testing of small biogas digester.
AID/Africa Bureau Ghana	Ghana Pyrolytic Converter Demonstration project will involve installation and testing of prototype 6 ton/day pyrolytic converter at BRRI brickworks kiln in Fumesua, Ashanti. Project follows 1976 feasibility study by Georgia Institute of Technology which indicated that conversion of Ghana's forestry and agricultural wastes into solid and liquid fuels could meet significant portion of future energy needs.
AID/Africa Bureau Lesotho	Component of Lesotho Renewable Energy Technology project involves testing and evaluation of experimental feedlot--based biogas system.
AID/Asia Bureau Indonesia	$125,000 pyrolitic conversion project with Institute of Technogy at Banding (Appropriate Technology grant).
AID/Asia Bureau Nepal	FY 80 - $75,000 to continue training Nepalese in construction and use of biogas plants.

BIOMASS

AID/Asia Bureau Philippines	Wood-fired (ipil-ipil species) power plant and rice-husk fueled power plant - $4 mm component of $7.1 mm loan/$1.55 mm grant to Philippine government for project in analysis, training & technology demonstration in non-conventional energy.
AID/Asia Bureau Thailand	Biomass demonstration as component of $5 mm project in renewable and non-commercial energy. Also includes feasibility study of village woodlots.
AID/DSB/EY	Bioresource Energy Production Project is intended to increase the availability of energy through more effective use of bioresources. Provides technical assistance (through U.S. Forest Service personnel) in design of technology and resource assessments to improve understanding of costs, socioeconomic impacts, environmental impacts, and technical requirements of bioresources. Includes field consultancies, case studies, and bioresource seminars. In FY 81, applied research and technology adaptation will begin. Total project cost FY 79-84: $8.1 mm.
AID/Latin American Bureau Dominican Republic	Energy Initiatives project includes $30,000 feasibility study of potential for ethanol production.
AID/Latin American Bureau Guyana	Study in planning phase would examine feasibility of using rice husks as fuel for electric power generation.

BIOMASS

AID/Latin American Bureau Panama	Biomass component of Alternative Energy Sources project will include feasibility studies of use of agricultural wastes for energy supply in rural areas. Wastes to be studied include rice hulls, and bagasse. Project also includes installation and testing of small isolated power plant fueled with scrap wood, and management of wood plantation to insure fuel supply for the power plant. Total project cost, FY 79-80: $825,000, of which $325,000 will go toward construction of plant and plantation. Project also includes two biogas demonstrations
AID/Latin American Bureau ROCAP Project (Central America)	AID's Regional Office of Central American Programs (ROCAP) Woodfuel Alternatives project includes (in addition to woodfuel production & conservation elements) study & testing of systems for biogas production, pyrolytic conversion, and direct burning of non-wood biomass and wood chips. Total project cost for FY 1979 and 1980: $1.7 mm.
AID/Near East Bureau Egypt	Applied Science & Technology project includes sub-project to test biogas systems in 5 demonstration villages.
DOE - Brazil	Memorandum of Understanding of February 1976 created Joint Group on Energy Technology, which will include alcohol production from biomass among areas for R&D, information exchange & training cooperation between U.S. & Brazil.

BIOMASS

DOE - Solar Program R&E	DOE's 1980 Solar Program R&D budget includes $58 million for biomass.
OECD Nations	As of April 1979, OECD member nations (including U.S.) reported 75 biomass projects with or for LDCs, including forestry projects.
World Bank	Between FY 76 and FY 80, the World Bank funded 4 projects in Gambia, Cameroon, Guyana and Barbados, involving studies and/or demonstrations of non-conventional biomass-based fuels for electric power generation. Fuel sources included ground-nut shells, rice-hulks and bagasse. Funding levels for these components of larger studies (tourism, rice production, forestry and electric power, respectively) are not available.

SOLAR

AID/Africa Bureau Cape Verde	Solar component of Cape Verde Renewable Energy project will include installation and testing of prototype solar cookers, fish dryers, stills, and air heaters for processing gypsum.
AID/Africa Bureau Mali	Five-year project will provide institutional support to Mail Solar Energy Lab; socioeconomic and meteorological surveys of 25 villages; applied R & D in solar water heaters, crop/fish dryers; photovoltaic battery charges, and photovoltaic pumps; and field training in 20 villages for villagers who will be responsible for operation and maintenance of solar devices. FY 1980 funding $500,000, total project $4.1 mm. Project management to be supplied by DOE's Solar Energy Research Institute (SERI).
AID/Africa Bureau Niger	Two-year Niger Solar Energy project will support Niger's Solar Energy Laboratory and permit experiments with collectors, concentrators, pumps and photovoltaic cells, and will provide irrigation water to farmers along the Niger River. FY 1978 funding $500,000.
AID/Africa Bureau Senegal	Senegal Renewable Energy project will support, as one of three technologies, development and testing of solar fish dryers. Total project funding request for FY 81: $1 mm.
AID/Africa Bureau Senegal	Senegal Bakel Irrigated Perimeter project will provide joint U.S.-French financing for installation of 30 KW thermodynamic pump in Bakel to irrigate up to 200 hectares and produce 20 kWh/day of electric power. Pump to be evaluated as alternative to diesel irrigation pumps installed in area through ongoing U.S.-financed crop production project.

AID/Africa Bureau Upper Volta	Upper Volta Solar Cell Power System Demonstration Project involves construction and installation of 1.8kW photovoltaic system in Tangaya to power grain grinding and water pumping. NASA/Lewis Research Center has implemented project with FY 78 outlay of $80,000 in Africa Bureau funds.
AID/Asia Bureau India	FY 78 - $2 mm for projects in Technology for the Rural Poor. 2/3 of that for alternative energy sources. Includes: solar dryers, solar collectors, & study/demonstration of several solar technologies. FY 80 funding for similar projects -- $2.4 mm.
AID/Asia Bureau Nepal	Radio Education project - includes component for communications applications of photovoltaic panels.
AID/Asia Bureau Philippines	Solar grain & lumber dryers, solar-powered ice plant for fishing village to be constructed as part of $7.1 mm loan/$1.55 mm grant to Philippine government for project in analysis, training & technology demonstration in non-conventional energy.
AID/DSB/EY	Project in Energy Production Through Photovoltaic Technology, operated by NASA/Lewis Research Center and DOE, is designed to demonstrate the cost-effectiveness and prove the technical and socio-economic feasibility of using, designing, and maintaining PV devices and systems to meet selected energy requirements. In FY 79 and 80, 6 PV refrigeration systems were installed in rural health centers for storing medicines. Prototype PV system for health clinics was developed, and two were installed in Africa and Latin America. FY 81 program will provide for similar development and field application of PV systems for rural education centers. Total project cost: $3.5 mm over FY 79-81.

SOLAR

AID/Latin American Bureau Panama	Solar component of Alternative Energy Sources project will include demonstration projects in air conditioning, hot water heating & photovoltaics.
AID/Latin American Bureau Jamaica	Alternative Energy Project planned for FY 1981 will include solar water heating and solar cooling.
AID/Latin American Bureau Bolivia	Appropriate Technology project includes installation and testing of solar water heating systems.
AID/Near East Bureau Jordan	Planning for FY 1981 includes solar component of proposed Science & Technology project, to use solar energy in water desalination plant.
AID/Near East Bureau Tunisia	Renewable Energy Project includes village-level and agricultural uses of solar, including photovoltaic irrigation pumps. Also includes management training for introduction of solar into Tunisian energy system.
DOE Solar Program	Although not aimed at LDC's, the DOE Solar Program includes the following components which may provide useful results for LDCs (all figures are FY 1980):

Total DOE Solar Program	- $667 mm
DOE Solar Technology Program	- 447 mm
DOE Solar Application Program	- 155 mm
Active Heating & Cooling	- 67 mm
Passive Heating	- 35 mm
Agricultural-Industrial Process Heat	- 35 mm
Photovoltaics	- 159 mm
Solar International Program	- 0 mm*

* $15 mm requested for FY 1981

DOE - Israel	1978 Memorandum of Intent anticipated U.S. Israeli cooperation on solar. Final agreement under review.
DOE - Korea	Draft agreement would establish cooperative relationship between U.S.'s SERI and Korean SERI.
DOE - Mexico	Solar was identified as one of 20 areas for possible U.S.-Mexican R&D cooperation following Feb. 1979 Memorandum of Understanding on Scientific & Technical Cooperation. Development of solar village in Mexico has been approved as joint project.
DOE - Saudi Arabia	Oct. 1977 agreement set up $100 mm, 5-yr. program of U.S.-Saudi cooperation on all types of solar technology development & transfer. Includes development of model solar village.
OECD Member Nations	As of April 1979, OECD member nations (including U.S.) reported 161 current or planned solar projects with or for LDCs, including 30 for solar heating, 6 for solar cooling, and 18 for solar electirc.
World Bank	The World Bank's education projects in Liberia, Gambia and Sierra Leone have included funds to install solar hot water heaters in the residences of school headmasters. Precise expenditure levels are unavailable. The Bank has also funded solar research in Israel (solar pond development), Bolivia (solar applications for rural needs), West Africa (solar for regional development) and -- in cooperation with UNDP -- in the Philippines, India, Sudan and Mail (solar-powered irrigation pumps).

WIND

AID/Africa Bureau Cape Verde	Component of Cape Verde Renewable Energy project will include installation and testing of wind systems for water pumping, and feasilibity study of combined wind electric/hydro system in Terrafal. Dutch wind expert will assist in project.
AID/Asia Bureau Philippines	Several small wind-machine demonstrations as part of $7.1 mm loan/ $1.55 mm grant to Philippine government for project in analysis, training and technology demonstration in non-conventional energy.
AID/Latin American Bureau Bolivia, Guatemala, Honduras, Peru, Dominican Republic & caribbean Region	Projects in appropriate technology and/or rural development in these countries all include wind-related components.
AID/Near East Bureau Egypt	Subproject of Technology Transfer & Manpower Development Project includes year-long wind output measurement in various locations, testing of 17 windmill designs & construction of best windmills in best locations.
DOE - Solar Program R&D	DOE's FY 1980 includes $63 mm for wind-related R&D.
OECD Member Nations	As of April 1979, OECD member nations (including U.S.) reported 27 wind energy projects with or for LDCs.

AID/Africa Bureau Lesotho	Component of Lesotho Renewable Energy Technology project involves testing and evaluation of one mini-hydro unit (3-5kW).
AID/Asia Bureau Philippines	Mini-hydro installations as part of $7.1 mm loan/$1.55 mm grant for project in analysis, training and technology demonstration in non-conventional energy.
AID/Asia Bureau Thailand	Demonstration of mini-hydro as component of $5 mm project in renewable and non-commercial energy, to be carried out by National Energy Administration of Ministry of Science, Technology & Energy.
AID/DSB/EY	Small Decentralized Hydropower project in FY 1980 assembled group of specialists to provide technical support and service to host countries and A.I.D. missions, train LDC participants, assess small hydropower potentials in host countries and develop plans and programs. Field consultancies were provided to twelve countries in Latin America, Asia, Africa and Near East. Small hydropower activities were developed as integral components of other developmental activities addressing irrigation, potable water supply, agriculture and small industry needs. Local capability to manufacture needed components of small hydropower systems was assessed in four countries. A training program was prepared. In FY 81, filed consultancies will be continued. Feasibility studies incorporating technical, economic and social/cultural factors will be made and preliminary engineering packages for candidate hydropower sites prepared. Training of LDC participants will begin with 40 participants from 10 countries anticipated. Total project cost FY 80-83: $3.2 mm.

MINI-HYDRO

AID/Latin American Bureau Panama	Mini-hydro component of Alternative Energy Sources project will involve identification of potential sites and feasibility studies for the 40 most promising. Total project cost FY 79-80: $825,000; estimated cost of mini-hydro studies: $50,000, to be contributed by Panama's Hydraulic Resources & Electrification Institute (IRHE).
AID/Latin American Bureau Peru	Integrated Rural Development project includes several mini-hydro sub-projects, including 500 kw mini-hydro dam at Huasahuasi.
OECD Member Nations	As of April 1979, OECD member nations (including U.S.) reported 8 mini-hydro projects with or for LDCs.
United Nations System	Technical panel of hydropower has been organized in preparation for 1981 Conference on New and Renewable Energy. UN recently completed report on small-scale hydro for UNCSTD. UNIDO has undertaken case studies as part of "Exchange of Experience and Transfer of Technology and Know-How on Mini-micro Hydrogenerator Units", and had collected information on LDC plans and projects and is preparing guidelines and information for interested LDCs. UN and UNIDO have organized several tours of Chinese mini-hydro installations.

GEOTHERMAL

AID/Asia Bureau Philippines	Philippine government has expressed preliminary interest in including geothermal as area for funding under security supporting assistance program (SSA).
AID/Asia Bureau Thailand	Assessment of geothermal resource as component of $5 mm project in renewable and non-commercial energy, to be carried out by National Energy Administration of Ministry of Science, Technology & Energy.
AID/Latin American Bureau Caribbean Region	Feasibility study of geothermal to be included in Caribbean Alternative Energy project.
AID/Near East Bureau Portugal (Azores)	AID team requested by Regional Government of Azores to evaluate data from past geothermal exploration and identify promising areas for further exploration.
DOE - R&D	FY 1980 budget includes $140 mm for geothermal R&D, some part of which might be applicable to LDC's.
DOE - Mexico	July 1977 U.S.-Mexican treaty set up 5-year agreement to survey Cierro Prieto geothermal field & determine most economical approach to its development. DOE's Lawrence Berkeley Lab is managing survey & study. Feb. 1979 Memorandum of Understanding on Scientific & Technical Cooperation also led to identification of geothermal as one of 20 areas for possible R&D cooperation.

GEOTHERMAL

OECD Member Nations	As of April 1979, OECD member nations (including U.S.) reported 19 geothermal energy projects with or for LDCs.
United Nations System	Technical panel on geothermal has been created in preparation for 1981 Conference on New and Renewable Energy. Economic & Social Commission for Asia & Pacific (ESCAP) has convened expert group on geothermal, and Economic Commission for Europe has studied use of geothermal energy for space heating. UN held symposia of geothermal in 1970 and 1975, and Report on Secretary-General on Status of Geothermal Energy and Future Prospects for Developing Countries was presented to Committee on Natural Resources in 1977. UNDP has financed geothermal projects in Djibouti, Ethiopia, Greece, India, Jordan, Kenya and Romania.
World Bank	Since FY 77, the World Bank has funded seven geothermal projects in four countries -- El Salvador, Kenya, Honduras and the Philippines. These efforts have ranged from preliminary studies and exploration (e.g., Honduras) to actual installation of geothermal electricity generating capacity (e.g., El Salvador, Kenya).

OCEAN ENERGY

OECD Member Nations	As of April 1979, OECD member nations (including U.S.) reported one sea energy project with or for LDCs.
DOE - Solar Program R&D	DOE's FY 1980 Solar Program R&D budget includes $46 mm for ocean thermal energy R&D (not aimed at LDC's, but potentially useful to them in the long term).

AID/Africa Bureau Rwanda	Rwanda Renewable and Improved Traditional Energy project will support Centre d'Etudes et d'Applications de l'Energie au Rwanda in designing, developing and field testing energy technologies which meet rural energy needs based on selected village-level surveys. FY 1979 funding $479,000.
AID/Asia Bureau Bangladesh	Preliminary planning for FY 81 alternative energy project ($2.2 mm). R&D component includes alternative energy pilot projects.
AID/Asia Bureau Indonesia	$800,000 alternative energy subproject of Science & Technology loan/grant--to be defined.
AID/Asia Bureau Pakistan	Before aid suspension, mission proposal for $500,000 FY 80 non-conventional energy project.
AID/Asia Bureau Regional Project	$500,000 over 2 years to the Resource Systems Institute for project on Energy and Rural Development. Includes component on: Introduction of Appropriate Rural Energy Mixes with Emphasis on Renewable Resources.
AID/DSB/EY	Project in Low Cost Technology for Rural Poor, for which Volunteers in Technical Assistance (VITA) are principal contractors, seeks to inform, educate and advise rural people on the efficient use of energy supplies and on the application of low-cost technologies using renewable energy resources. Program for FY 81 to include: provision of technical consultancies for specific problem solving, technical responses in appropriate language and formats, development of renewable energy networks to supply rapid information to energy workers, publication of practical publications on renewable energy technology, training programs, and provision of small grants to LDC-PVO organizations working directly with low-income peoples on alternative energy technologies. Total project cost FY 79-81 $3.9 mm.

MIXED RENEWABLES

AID/DSB/EY	Renewable Energy Survey and Demonstration project, carried out by Peace Corps, is to survey energy needs & resources of rural areas as basis for planning small-scale renewable energy projects, and to train PCV's and support their efforts to use small-scale renewable energy technologies in rural areas. Peace Corps has developed rural energy survey methodology and field tested it in Philippines, Micronesia, Senegal and Paraguay. FY 81 program will extend rural energy surveys to 8 countries and will analyze data received in FY 80 surveys. Up to 50 additional PCV's will be trained, and renewable projects initiated in FY 80 will undergo initial evaluation. Total project cost, FY 79-81: $1.45 mm.
AID/DSB/EY	Project in Training in Alternative Energy Technology, carried out by University of Florida Solar Energy & Energy Conversion Laboratory, is to provide short-term training in alternative energy technologies, particularly small-scale solar, and to strengthen LDC institutional capabilities in this area. Will include two 15-week courses in U.S. per year, with 30 participants in each. In FY 81, will begin efforts to establish similar program in an LDC institution. Total project cost FY 79-83: $6 mm.
AID/Latin American Bureau Dominican Republic	Energy Policy Development project includes assessment of renewable energy potential as part of overall assessment of supply and demand and preparation of National Energy Plan. Total project cost, FY 80-81: $634,000. Follow-up project in Energy Conservation & Resources Development, planned for FY 81, will include demonstration and testing of renewable sources including wind, solar, mini-hydro & biomass. Project cost (total), FY 81: $5 mm.

MIXED RENEWABLES

AID/Latin American Bureau Caribbean Regional Project	Caribbean Alternate Energy Systems project, carried out by Caribbean Development Bank and Caribbean Community, will examine potential applications of a broad range of renewable technologies to alleviate the region's extremely heavy reliance on imported oil. FY 1980 project cost: $1.2 mm.
AID/Latin American Bureau Costa Rica	Costa Rica Science & Technology project includes $1.35 mm energy component that may include geothermal R&D; feasibility studies of alcohol, solar, wind, other biomass; and survey of wood species characteristics (including potential energy uses).
AID/Latin American Bureau Ecuador	Alternative Energy Sources project.
AID/Latin American Bureau Haiti	Appropriate Technology project will include small rural applications of renewables including windmills, solar dryers, etc.
AID/Latin American Bureau Honduras	Rural Technologies project includes renewable energy component involving solar data collection and testing of renewable technologies (wind generators, solar grain dryers, more efficient charcoal production systems, etc.) for rural enterprises.
AID/Near East Bureau Egypt	Planned Renewable Energy project of $20-25 mm over 4-5 years would involve broad U.S.-Egyptian cooperation in several renewable energy areas (wind, solar, biomass, geothermal).
AID/Near East Bureau Morocco	Energy Development Project will establish National Renewable Energy Center for R&D, planning, training & coordination of renewable energy development. FY 1980: $800,000.

MIXED RENEWABLES

AID/Near East Bureau Yemen Arab Republic	Appropriate Village Technology Project includes renewable energy component involving village-scale electricity, biogas, wind & solar.
OECD Member Nations	As of April 1979, OECD member nations (including U.S.), reported 50 mixed renewable energy projects (including institutional and supportive programs) with or for LDCs.
World Bank	The Bank's proposed FY 80-81 general energy research agenda includes a study of traditional and non-conventional energy sources and technologies. In addition, proposed studies entitled "LDC Energy Outlook" and "Energy and Development" are expected to examine the potential role of renewables.

CONSERVATION

AID/Asia Bureau Bangladesh	Preliminary planning for FY 81 alternative energy project ($2.2 mm). Includes, as 1 of 5 main functions: insuring efficient energy use & conservation.
AID/DSB/EY	Energy Efficiency and Conservation project will encourage more efficient use & conservation of energy resources through such means as improved operations and maintenance, retrofitting of existing equipment and better choice of future equipment. Initial efforts include case studies of selected industries. FY 81 will include 2 regional seminars on energy efficiency & investment for LDC planners and industry managers, energy analyses of energy-intensive installations, advice and consultation on retrofitting and investment and technology choices, and workshops for representatives of energy intensive sectors. Total project cost, FY 80-84: $6.5 mm.
AID/Latin American Bureau Dominican Republic	Energy Policy Development project includes conservation programs within context of National Energy Plan. Follow-up project in Energy Conservation & Resources Development is planned for FY 81, and will include implementation of conservation programs in end-use sectors such as transportation and industry. Total costs, FY 80-81: $5.6 mm.
AID/Latin American Bureau Jamaica	Alternative Energy project planned for FY 1981 will include effort to implement conservation in large buildings, especially tourist hotels.

CONSERVATION

DOE - Brazil	Memorandum of Understanding of Feb. 1976 created Joint Group on Energy Technology, which will include conservation in industry & transportation among areas for U.S.-Brazilian cooperation in R&D, information exchange & training.
DOE - Korea	Preliminary discussions between DOE and Korean Institute of Energy Conservation may lead to sister-lab relationship between KIEC and Argonne National Lab.
DOE - Mexico	Energy conservation has been identified as one of 20 areas for possible U.S.-Mexican cooperation following Feb. 1979 Memorandum of Understanding on Scientific & Technical Cooperation.