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Renewable Energy Sources for the World's Poor: A Review of Current International Development Assistance Programs

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SERI

Solar Energy Research Institute

A Division of Midwest Research Institute

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**RENEWABLE ENERGY SOURCES FOR
THE WORLD'S POOR:**

**A REVIEW OF CURRENT INTERNATIONAL
DEVELOPMENT ASSISTANCE PROGRAMS**

JOHN H. ASHWORTH

OCTOBER 1979

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PREPARED UNDER TASK NO. 4326.50

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FOREWORD

This report documents work performed under Task No. 4326.50. The author wishes to acknowledge the extensive assistance provided by David Brunel in the preparation of the Appendices and in the gathering of the project information. The author also wishes to thank Donna Downing of the Policy Analysis Branch and Carol Shea of the International Programs Branch for their invaluable aid in assembling portions of this report. More than a dozen outside reviewers from a wide variety of foreign assistance organizations read successive drafts of this paper, providing valuable comments and criticisms which have helped to sharpen the analysis and broaden the coverage of the text.

Approved for:

SOLAR ENERGY RESEARCH INSTITUTE

James W. Doane, Chief
Policy Analysis Branch

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SUMMARY

In the past six years, spiralling costs of conventional energy have caused massive balance-of-payments problems for developing countries, slowed agricultural development projects, and accelerated environmental degradation due to overuse of traditional fuels (especially firewood and dung).

A number of national and international solutions have been developed for these changes in energy prices and availability. This paper addresses one facet of the worldwide effort to expand the energy supplies for developing countries: foreign assistance funding for the creation, testing, and use of renewable energy sources. The bulk of the text, Section 2.0, provides information on more than 30 projects that are large, innovative, or indicative of future large-scale assistance programs. For ease of analysis, these projects are divided into seven program areas: baseline data collection, renewable resource creation and management, institution building, technology and hardware development, demonstration and field testing, integrated energy self-sufficient villages, and manpower training. Each category explains why such projects are important to developing country planners and donor officials and how they relate to other renewable energy programs.

While the number of donor projects for renewable energy has been growing rapidly in the past five years, there has been little sharing of acquired knowledge. The efficacy of many projects would be greatly increased by the agreement of all donors to two concepts: the coordination of renewable energy project design and administration, and the exchange of technical information generated by each project. The minimal requirements for each renewable energy project would include baseline data collection, the evaluation of the performance of the technologies employed, an analysis of the impact of external factors on the performance of the energy system, and an estimate of the changes induced by the introduction of the renewable energy system. It is estimated that the range of minimal financial commitments would be 2%-4% of total project funding for baseline data collection and 4%-6% for the technology evaluation. The advantages of jointly funded projects are discussed briefly as well as the administration of these projects, including regional organizations and multidonor consortia.

Section 4.0 recommends U.S. activities that would encourage donor coordination and information exchange. These include the unilateral adoption of a uniform baseline data collection and technology evaluation methodology for all U.S. renewable energy projects, with the results distributed to all interested development planners and project officers. It also recommends that the United States develop, possibly through the Institute for Scientific and Technological Cooperation, a central clearinghouse for information on renewable energy in the Third World, including data from other bilateral donors, multilateral agencies, appropriate technology institutions, national research institutes, and specialized technology centers. Section 4.0 also advises that the United States consider quasi-experimental designs for renewable energy projects. These would include projects devised to provide data comparing the performance of different systems that perform the same work in the same location or projects with identical systems that face different external environmental factors. Both these types of projects would help to determine what influences project success and would help accelerate technology modification to meet local conditions. Section 4.2.2 discusses promoting joint ventures between U.S. firms and Third World nations, and the advantages for each party.

The last section discusses specific initiatives for U.S. foreign assistance in each of the seven major program areas. These initiatives either should supply needed information or should adapt programs developed by non-U.S. donors that appear to greatly accelerate the development process.

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NOMENCLATURE

ADI	aL Dir'iyah Institute
BOSTID	Board on Science & Technology for International Development, U.S. National Academy of Sciences
DTI	Domestic Technology Institute
FAC	Fonde d'Assistance et Cooperation (France)
FAO	United Nations Food & Agriculture Organization
ICAITI	Central American Institute for Industrial Research
IDB	Inter-American Development Bank
IDRC	International Development Research Center (Canada)
IEA	International Energy Agency
IER	Institute for Energy Research
ISTC	Institute for Scientific and Technological Cooperation
NAS	National Academy of Sciences
OAS	Organization of American States
ONERSOL	L'Office de l'Energie Solaire (Niger)
PACT	Private Agencies Collaborating Together
SAED	Société Africaine d'Études et de Développement (Upper Volta)
SIDA	Swedish International Development Agency
SOFRETES	Société Française d'Études Thermiques et d'Energie Solaire
UNCDF	United Nations Capital Development Fund
UNEP	United Nations Environmental Programme
UNICEF	United Nations International Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
UNDP	United Nations Development Programme
UNU/NRP	United Nations University Natural Resources Programme
USAID	United States Agency for International Development
VITA	Volunteers in Technical Assistance

SECTION 1.0

INTRODUCTION

In the last six years, changes in the international energy market transformed the planning environment in the developing countries of the world. To poor countries struggling with massive balance-of-payments deficits, the seven-fold rise in price of crude oil since 1973 has greatly decreased the attractiveness of fossil-fuel-intensive programs that were initiated in the late 1950s and 1960s and were designed to accelerate agricultural production through the use of hybrid seeds, irrigation, and chemical fertilizers. Rural electrification projects have been slowed due to spiraling fossil fuel prices or to uncertainties about nuclear energy. Proposed road construction projects now must be reconciled with restrictions on the use of imported liquid fuels and with restrictions on the availability of scarce foreign exchange.

National governments and the international development community have responded to the changes in energy prices and energy availability in a variety of ways. Extensive programs of exploration and development of fossil fuels have been initiated in areas formerly considered high-risk or marginal by the private sector. The production of indigenous deposits of coal and natural gas have been accelerated, particularly in the most industrialized less-developed countries (LDCs) such as India, Korea, and Pakistan. New conservation programs and new low-cost, efficient energy conversion devices have been created to help achieve basic development goals while preserving scarce indigenous energy sources or high-cost imported fuels. Several developing nations have launched ambitious, domestically funded programs to develop nonfossil fuel sources, such as the Brazilian alcohol development program [1] and the Philippine effort to tap its extensive geothermal energy resources [2].

This paper examines one facet of the rapidly expanding world-wide efforts to provide energy for Third World development: foreign assistance funding of the creation, testing, and use of renewable energy sources.*

The scale of international cooperation in renewable energy resources is still quite small (particularly when compared with the level of expenditures for nuclear technology, fossil fuels exploration, and large-scale hydroelectric dam creation), but it is growing rapidly. Donor agencies and developing nations give serious attention to technologies that were considered exotic and marginal only six years ago: small-scale hydroelectric generation, solar water heating and distillation, biomass conversion to methane gas and alcohol, wind power, photovoltaic-powered small-scale irrigation, and village-level solar-powered absorption refrigeration. Each month brings news of another planned small-scale demonstration project or of another Third World request of donor nations for technical assistance in renewable resource utilization.

*The terms "renewable energy source" and "solar energy device" are used interchangeably throughout this paper. This paper will follow the practice of the U.S. energy community and use the term solar energy broadly to indicate the whole range of nonfossil fuel energy sources, including biomass combustion, biogas generation, small-scale hydroelectric power generation, wind energy converters, flat-plate and concentrating solar collectors, and photovoltaic systems.

The coordination of these many renewable energy activities and the exchange of information about what has been learned have lagged behind the initiation of projects. In part, this is due to many renewable energy experiments being undertaken as a portion of a larger development program that may be oriented to an objective other than energy production (integrated rural development, irrigation, etc). Second, renewable energy projects are small and decentralized, with much of the activity occurring in remote sites. Little information is exchanged among donors on such projects, and what is shared is often passed informally only at the field or country level.

The need for analyzing information gained from donor activities and from national programs in renewable energy sources has been recognized in several quarters. Representatives of a number of Western bilateral donor nations met throughout late 1978 and early 1979 under the auspices of the Organization of Economic Cooperation and Development's International Energy Agency (IEA) to discuss program coordination and information sharing on foreign assistance projects that involve renewable energy sources. The United Nations is completing plans for a major international conference on renewable energy sources to be held in 1981.* This meeting will focus world attention on the need within the Third World to lessen dependence on imported fuel sources and to accelerate the search for alternative sources of energy for development.

This report is an initial effort to assist in the international coordination of donor activity and in the sharing of information generated by foreign assistance projects that use renewable energy sources. This paper has four major objectives:

- to systematically aggregate information on current activities of donor agencies from a variety of published sources, personal interviews, and correspondence;
- to provide more extensive information on selected projects that are innovative in design, large in size, or indicative of future large-scale assistance programs;
- to point out specific areas where donor coordination or information exchange should be accelerated; and
- to identify areas where the U.S. government might take a more active role in promotion of renewable energy sources for rural development.

The bulk of the report provides information about specific development projects. It contains only a fraction of the projects that have been approved and funded by 1 June 1979, and does not include the large number of projects that were in the planning stage as of that date. In such a rapidly changing field, it is possible only to present a partial picture at a given time. Because of the ready availability of such information to the Solar Energy Research Institute (SERI), a somewhat disproportionate emphasis is given to projects developed by the United States or by organizations headquartered in the United States. Little information has been developed on projects that are administered by small philanthropic and religious agencies, particularly when they have a decentralized planning structure. The same is true of the activities of certain small European donor nations, as well as activities involving technical cooperation among developing countries. For easy reference, Appendix A lists all the identified foreign assistance

*The 1981 date for the U.N. Conference on New and Renewable Sources of Energy was chosen in part for its symbolic value. It marks the twentieth anniversary of the 1961 U.N. Conference on New Sources of Energy, one of the first international gatherings to address substantively the possibilities of alternative energy sources.

projects that use or develop renewable energy sources. This list will be continuously updated in SERI project files to reflect new donor initiatives or new project information. The analysis is restricted to projects with two characteristics: an emphasis on renewable energy sources and outside donor funds. Thus, the report does not include appropriate technology* projects not focusing mainly on energy production or usage, even when they might result in reductions of fossil fuel consumption (i.e., reforestation programs and proposals to develop bicycle-powered transport vehicles). It also does not include national programs in developing areas that are funded without participation by donor agencies or international organizations (such as the extensive, internally financed national research efforts in Brazil and India). Data on the size and cost of individual projects are estimates from donor agencies and are subject to major modifications, depending upon how well the systems and experiments proceed in the initial phases.

*Appropriate technology is used in this report to signify low-cost, capital-sparing, simple systems. A more complete definition drawn from a standard text in the field is that appropriate technology "involves a low-cost, labour-intensive, and small-scale processes and equipment. It utilizes local energy sources, and is characterized by simplicity, facility of maintenance, and minimal operating costs. Usually, it is applied to alleviate the unemployment and hardship of the rural poor, who have been largely bypassed in many development assistance efforts" [3].

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SECTION 2.0

CURRENT DONOR ACTIVITIES

There are a number of ways that donor activities in a technical field can be organized: by donor organization, recipient country or region, implementation mechanism, or the technologies employed. In order to facilitate the coordination and information exchange among donor agencies, projects in this report are grouped according to the analytic focus of the renewable energy portion of the project; i.e., what did the developing country or the donor agency hope to learn about the renewable energy technology or accomplish through its use? After initial discussions with officials of bilateral, multilateral, and private agencies, several disparate reasons were isolated that explain why donors and developing countries have identified and initiated energy development assistance projects. Project description documents and field reports were examined also so as to limit the number of project types to manageable size. The following seven major categories of renewable energy projects were identified.

- Baseline Data Gathering
- Renewable Resource Creation and Management
- Institution Building
- Technology and Hardware Development
- Demonstration and Field Testing
- Integrated Energy Self-Sufficient Villages
- Manpower Training

Many projects attempt to engage simultaneously in more than one of these activities. In most cases, a project was assigned to one category according to the portion of the project requiring the most human and financial resources. It should be emphasized that these categories are applicable only to the renewable energy portions of a project and may have little to do with its overall development objectives. For example, a donor might have funded a project whose objective is to provide drinking water to remote mountain villagers and their herds. As one part of this project, the donor agency is testing a number of solar pumping configurations to determine which ones are more durable, resistant to high winds, and compatible with existing power-conditioning equipment. This would be considered a field-testing project, despite the overall objective of water provision.

2.1 BASELINE DATA GATHERING: ENERGY USAGE AND RESOURCE AVAILABILITY

One of the major problems confronting Third World development planners and officials of donor agencies is that they have very little information on the use of energy in the countryside and in urban slums, the cost of available fuels, and the substitute renewable energy sources available in each area. Such data must be collected before specific configurations can be designed and before choices between alternative energy systems can be made. How much animal and human refuse is available for a methane digester? What is the daily average solar insolation? Is there a stream bed that would be appropriate for small-scale, instream hydroelectric power systems? The following projects are

trying to provide admittedly rough answers to these types of questions, so that development planners can estimate the costs and benefits of proposed alternative projects.

2.1.1 World Bank Wood Energy Usage Surveys, Mali and Burundi

The World Bank system, through its soft-loan arm, the International Development Association, has recently approved credits of \$4.5 million and \$4.3 million for surveys of energy usage patterns in Mali and Burundi, respectively. This project also will include the continuous monitoring and evaluation of wood-burning systems and the promotion of more efficient wood-burning stoves and charcoal kilns in these two countries.

2.1.2 Peace Corps Data Collection Project*

The U.S. Peace Corps and the Overseas Development Council, with a grant from the aL Dir'iyah Institute, have completed collaborative plans with the United States Agency for International Development (USAID) to train Peace Corps volunteers to collect energy usage data in the field and to provide simple observations about the suitability of the local climate for renewable energy systems (wind energy converters, small-scale hydroelectric generators, photovoltaic arrays, and flat-plate collectors).

The Peace Corps will dispatch training teams to conduct one-week in-country workshops on renewable energy for volunteers and host country counterparts, and to acquaint these field workers with the data collection instrument developed by the Overseas Development Council. The training teams later will visit selected volunteers in their villages to solve specific problems and reinforce the training. The Peace Corps plans to use male-female data collection teams in each village (to eliminate any sex-related cultural bias) and hopes to involve local researchers and village leaders. Initially, the workshops will run in seven countries in 1979, with the effort concentrated in Latin America and Africa. In 1980, the project will expand to 15-20 countries, and an additional five to seven country programs will be initiated in 1981. The project in each country will take approximately one year to complete. USAID is providing \$1.5 million in direct and indirect expenses. It is hoped that this project will provide not only a large collection of baseline data but also will assist in the identification of future projects for the Peace Corps and USAID.

2.1.3 Colombian Rural Energy Study

In May 1977, the World Bank initiated a project with the government of Colombia to gather information on rural energy problems, including "demand, supply, institutional, and technology aspects" [4, p. 99], and to identify and develop projects for the Bank to fund. The assessment of needs and supplies was prepared by an interdisciplinary group of Colombian government officials and included a large case study of Antiquia. The initial report was completed by the beginning of 1978. This program has entered its second phase, which includes a comprehensive national rural energy development plan, demonstration projects, training programs, the creation of local manufacturing

*The following information is drawn from interviews with Peace Corp staff, USAID Program planners, and Overseas Development Council analysts during April 1978-March 1979.

capability, and the development of indigenous energy and appropriate technology institutions.

2.1.4 IDRC/University of the South Pacific Data Collection

The International Development Research Center (IDRC), a Canadian crown corporation that supports rural development projects throughout the world, contracted in 1976 with a research group from the University of the South Pacific to survey the current and future energy requirements of local village communities. The project was designed not only to gather baseline data, but also to examine the feasibility of alternative renewable energy resources (particularly biogas generators), with an eye toward creating local manufacturing facilities [5, p. 13].

2.1.5 U.S. International Energy Development Program (IEDP)

In September 1977, the United States with selected developing countries initiated a pilot program of cooperative energy resource assessment and management. The U.S. Department of Energy manages the program under the policy direction of the U.S. Department of State. The overall U.S. objective is to help developing countries strengthen their energy planning capabilities. There are three specific aims for the program:

- to reduce the developing country's dependence on imported oil and to minimize the adverse impact of world energy prices;
- to encourage the development of indigenous energy resources, including the use of renewable resources; and
- to avoid premature commitments to the use of nuclear energy.

Cooperative programs were conducted with Egypt and Peru during 1978. They included systematic assessments of energy resources; projections of energy demand and supply availability; examination of the materials, equipment, and manpower needs for alternative energy planning strategies; and the development of the capacity to meet these needs. As part of the initial Egyptian assessment, more than 40 U.S. government resource and energy experts traveled to Egypt and collaborated with their Egyptian counterparts. A substantial computer modeling exercise also was initiated at the Brookhaven National Laboratory to simulate the impacts of various energy supply and demand alternatives [6, pp. 6-74].

The IEDP program will expand in 1979 and 1980 with assessments planned for four new countries each year. Thus far, Argentina, Portugal, and South Korea have agreed to participate in 1979. The U.S. financial share in the IEDP program is approximately \$2 million per year.

2.1.6 ADI/IER Energy Information System for LDCs*

Under a long-term grant of \$300,000 per year from the aL Dir'iyyah Institute (ADI), the Institute for Energy Research (IER) of the State University of New York at Stony Brook

*This information was provided by officials of the aL Dir'iyyah Institute and by Dr. Robert Nathans of IER.

is developing a sophisticated energy information network for developing countries. This system, designated by the acronym AL-EDIS, will give Third World planners and researchers direct access through remote computer terminals to econometric projection models, energy supply/demand figures, as well as technical and cost characteristics of new energy technologies. This system also will be tied to the various components of the Solar Energy Information Data Base, located at SERI. This linkage will provide developing countries with information on available renewable energy systems, manufacturers, costs of systems, current and planned foreign assistance programs using solar energy, solar energy researchers throughout the world, and worldwide energy resource estimates. AL-EDIS will be fully operational in 1981.

2.2 RENEWABLE RESOURCE CREATION AND MANAGEMENT

Many donor agencies have long been active in Third World forestry management and forest crop improvement. Until recently, this foreign assistance was directed toward the commercial development of forest products, with the objective of expanding production (on a sustainable basis) of lumber and paper products for domestic and export markets. Within the last five years, national governments and donor agencies have increasingly paid attention to the creation of village woodlots and similar facilities that are strictly for the production of firewood and charcoal as fuel. These projects seek to increase the supply of traditional fuels rather than to introduce new energy systems as substitutes for current fuel sources. Many of the woodlot programs were developed both to counter the increasing scarcity (and soaring cost) of firewood in villages and urban areas and to ease the environmental damage caused by overcutting of trees and shrubs in arid regions.

2.2.1 UNDP/FAO Charcoal Production Project in Ghana

As part of an effort to increase available charcoal for both industrial and residential use, the United Nations Development Programme (UNDP) is providing \$1.4 million to the government of Ghana for a three-year program to accelerate charcoal output and to increase the efficiency of wood conversion into charcoal. The United Nations Food and Agriculture Organization (FAO) acts as the UNDP executing agency for this project, which is linked to a large-scale reforestation project conducted by the Ghanaian government. For the last several years, the government of Ghana has annually been clearing 9,200 hectares of forest land in order to plant faster growing trees for pulp production and commercial timber operations. Over 460,000 cords of wood are cut annually to make way for the new tree species. The UNDP/FAO program uses portable kilns to convert this formerly wasted wood into charcoal. There are 22 kilns in operation that should yield 50 tons of charcoal per month when the program is complete. This charcoal will be used for domestic needs and possibly for export. Consideration also is being given to the creation of indigenous cement, iron, and steel facilities fueled by this renewable source [7].

2.2.2 Upper Volta Firewood/Reforestation Program

A consortium of multilateral, bilateral, and private donors are cooperating with the government of Upper Volta to develop village-level woodlots, providing firewood on a sustainable yield basis. The firewood development effort is part of a reforestation project that has been underway since 1975 and involves participation by such varied donors as the UNDP; FAO; governments of Canada, West Germany, and Switzerland;

Christian Aid; and Cathwell. In 1977 alone, more than 100 village plantations were established, totaling more than 180 hectares. Using fast-growing, drought-resistant tropical species such as eucalyptus and cassia, the woodlots begin to yield firewood within two to three years after the initial planting. Involving the local village leaders in the planning and execution of the project has ensured protection of the trees from foragers and commercial firewood gatherers while providing a local mechanism for the care and tending of young trees [8].

2.2.3 Rural Electrification from Wood Wastes, Samoa*

The UNDP is completing engineering feasibility studies for a large, rural electrification project on the island of Savai'i in Samoa. The electrical generator will be powered by the combustion of wood wastes and sawdust from a commercial sawmill on the north side of the island. The UNDP has provided \$257,000 for detailed feasibility and engineering studies and for technical assistance. In addition, United Nations Capital Development Fund (UNCDF) will allocate \$1,374,000 for additional generating equipment, 90 km of high-voltage transmission lines, substations, and a 60-km residential-distribution network. It is estimated that electrical power will be provided to 31,000 of the island's 42,000 inhabitants at a price of under 7¢/kWh. This project is part of a \$16 million multidonor electrification program for Savai'i, with additional funding provided by the International Development Association, the European Development Fund, FAO, and the governments of Australia and New Zealand.

2.3 INSTITUTION BUILDING

One of the major objectives of most international assistance programs is to increase the capacity of the host country to plan and administer development projects. In some cases, this involved the provision of technical advisors to governmental agencies. In the case of rural energy planning and research, it often has meant the creation of new institutions and research centers. These organizations, whether new or long-established, serve as the nexus for a whole gamut of renewable resource programs, ranging from baseline data collection and project identification to hardware fabrication and fundamental research into materials and systems.

2.3.1 VITA/PACT Documentation Center, Upper Volta

Under a grant from an international consortium funding agency called PACT (Private Agencies Collaborating Together), the Volunteers in Technical Assistance (VITA) and the local Société Africaine d'Études et de Développement (SAED) are jointly creating a resource and documentation center for appropriate technology in Ougadougou, Upper Volta. It will serve as a clearinghouse for information drawn from the worldwide appropriate technology network. VITA provides one full-time volunteer and the Peace Corps has sent two trained librarians to work at the center for two years. VITA is considering setting up similar documentation centers in other African nations [9, pp. 6-7].

*This information was provided by UNDP technical advisors.

2.3.2 UNDP/FAC Solar Energy Program, Niger*

Under the leadership of Dr. Abdou Moumouni, Niger has long been a leader in the development and deployment of solar systems. The UNDP has provided funds for the establishment of a regional solar energy center in Niamey, Niger, while the French Fonds d'Assistance et Cooperation (FAC) and USAID also provide funds to ONERSOL (Organization Nigerienne de l'Energie Solaire) under Dr. Moumouni's direction to develop and fabricate a number of solar products. Work is underway on a solar furnace, flat-plate collectors, and a hybrid system that combines a concentrating tracking parabolic collector with a flat-plate system. In 1979, ONERSOL will work in conjunction with the French firm SOFRETES (see Section 2.5.5) to develop one 5-kW and one 10-kW irrigation system, using French Rankine cycle engines and locally produced flat-plate collectors. At present, ONERSOL produces six solar hot water systems per day for commercial sale and use on government buildings in Niger [10, pp. 28-31].

2.3.3 SIDA/Arusha Appropriate Technology Project, Tanzania

The Swedish International Development Agency (SIDA) funds the operation of an appropriate technology center in Tanzania. This program is aimed at building capacity to adapt, fabricate, and install simple small-scale technologies, including renewable energy sources. One major area of interest is low-cost windmills.

2.3.4 Mali Solar Energy Laboratory

As part of the Mali Renewable Resource Project, funded recently by USAID, the United States will provide funds for new facilities, equipment, and technical advisors for the Mali Solar Energy Laboratory. SERI will implement the project on behalf of the U.S. government. As part of the five-year agreement, the staff size of the Mali Solar Energy Laboratory will be enlarged, and members will be trained in various solar technologies both in western Africa and in the United States.

With this assistance the Solar Energy Laboratory will undertake several pressing tasks, including the testing and improvement of solar water heaters, the testing and development of crop/fish dryers, the creation of locally fabricated, efficient wood stoves, and the development of a photovoltaic battery charger [11, p. 3].

In addition to these institution-building tasks, the USAID/Mali Renewable Resource Project will collect baseline energy usage and resource availability data at 25 villages and will train village-level cadres to maintain and operate solar collectors, test systems, and evaluate the results of the solar units. The planned installations for this project are discussed in detail in Section 2.5.3. The total proposed U.S. contribution is \$3,910,000, with the government of Mali providing supervisory personnel and logistical support [11, p. 32].

*Portions of these sections are drawn from discussions with Dr. Moumouni of ONERSOL and with officials of SOFRETES.

2.4 TECHNOLOGY AND HARDWARE DEVELOPMENT

Once local energy requirements are roughly determined and the feasibility of using renewable energy resources is examined, local planning officials and donor agencies face three major options. First, they can use and test systems that are available from manufacturers in other countries or from technology clearinghouses to determine if these products are appropriate for the local climate and for usage patterns. Such an installation of hardware (usually imported) in a rural development project will be labeled in this report as a "demonstration project," and a number of them are outlined in a later section. Second, a local institution or government agency can engage in basic research and seek to develop indigenous energy systems by linking traditional practices with research on materials, system efficiency, and component durability. Several such programs have just been described. Third, the local research organization can adopt designs developed elsewhere as prototypes and can alter them to use native materials and local building or manufacturing practices that are compatible with local social and cultural patterns. This hardware development is often crucial in ensuring that solar systems are locally acceptable, durable, and appropriate to the needs of consumers. A number of centers have now been established in the Third World to perform both technology research and hardware development. Some of the larger and more advanced countries, such as Mexico, India, and Brazil, have extensive programs involving several national energy laboratories and university research programs. The programs listed below are much more modest: they seek either to commercialize equipment or to establish solar adaptation and manufacturing in areas without substantial previous solar experience.

2.4.1 Bolivian Antiplano Appropriate Energy Technology Project

At the end of 1977, the World Bank approved a four-year, \$165,000 project aimed at developing low-cost renewable energy hardware tailored to the harsh climate of Bolivia's rural mountain highlands (the Antiplano). These isolated communities rely domestically on the burning of animal dung. Despite low population densities, supplies of this fuel and other traditional noncommercial sources are, in the words of the World Bank staff,

inadequate to meet household requirements and provide only for limited cooking and no heating during the harsh winter months. Also, the employment of dried animal dung to generate energy eliminates its use as fertilizer. Alternative sources of energy for rural areas are critically important. [4, p. 101]

The World Bank seeks to promote rapid technology transfer and adaptation of solar technologies for a variety of rural needs, including "heating, cooking, pumping, food drying, and greenhouse agriculture" [4, p. 102]. This program is part of the larger \$18 million Ulla Ulla Rural Development Project sponsored by the World Bank.

2.4.2 IDB/ICAITI Technical Cooperation in Appropriate Technology*

The Central American Institute for Industrial Research (ICAITI) is conducting a two-year study for the Inter-American Development Bank (IDB) and several Central American governments on four small-scale technologies. The IDB provides \$650,000 in financial

*This information is drawn from interviews with IDB personnel.

support and ICAITI is allocating additional counterpart funds. Two of the four technologies being investigated are renewable energy systems: solar crop dryers and methane digesters. ICAITI already has undertaken a survey of the available technologies and of the range of applications in different parts of Central America. In the current phase of the project, systems will be developed and field-tested in several of the Central American countries, including Costa Rica and Honduras. Special attention will be paid throughout this project to the dissemination of information about these systems to potential users. One interesting aspect of this research will be the linkage of the solar dryer to a methane digester in order to ensure the drying of crops during the rainy season.

2.4.3 Solar and Hydropower Development Project, Nepal

The Swiss government provides technical assistance to a program that designs, manufactures, and sells small-scale hydroelectric generators, hydraulic rams, and solar collectors. A corporation (Bolaju Yantra Shala) has been set up in Katmandu for this research and hardware production. A recent report estimated that more than 18,000 litres of hot water are produced daily in Nepal by installed solar systems [12].

2.4.4 Israeli Solar Pond/Rankine Cycle Engine Development Program

The World Bank has committed \$5 million to assist in the commercialization of highly saline "solar" ponds as a source of heat and energy. The sun's radiant energy is trapped by the salt solution, which does not undergo thermal mixing but remains in distinct stratified layers. A prototype system designed for industrial use is being constructed. The World Bank also is funding further development of small Rankine cycle engines, which will be coupled to the solar ponds. These engines are designed to require little maintenance so that they will be able to "replace the small diesel engine in various village applications" [13].

2.4.5 "Las Gaviotas" Technology Development and Production

As part of a long-term program to encourage settlement of its llanos region, the government of Colombia since 1969 has operated an integrated rural development center, "Las Gaviotas." In cooperation with researchers from the Universidad de los Andes in Bogota, Las Gaviotas staff members have developed six simple, low-cost technologies to meet specific needs of llanos citizens [14, pp. 2-3]. Among these technologies are three renewable energy systems: a solar water heater, a low-head hydroelectric generator for \$140, and a wind-driven water-pumping system which costs less than \$310 and lifts 23 litres of water per minute from a depth of 25 m in a wind of only 4 m/sec [14, p. 3; 15, pp. 33-34]. With grants totaling \$800,000 from Dutch foreign assistance, the Colombian government, and the UNDP, the Las Gaviotas center will build a factory to mass-produce its six low-cost technologies. Initial plans call for production of more than 1,000 units per year [14, p. 2; 15, pp. 33-34].

2.5 DEMONSTRATION AND FIELD TESTING

Foreign assistance agencies have been most active in field-testing and demonstration projects. There are several reasons for this emphasis. First, demonstration projects can

be quickly planned and installed. Because the projects are highly visible and not terribly expensive, donor organizations that are under great pressure to "do something" in solar energy find them attractive. Second, they serve as excellent showcases for technologies that a major donor nation may be trying to export. Third, field-tests are necessary for the gathering of cost/output information under actual field conditions, data that are essential to planners considering further deployment of solar units. Fourth, carefully monitored field-tests assist in determining how solar technologies can be integrated into existing social systems. By testing the actual village units, planners and donor agencies can learn which configurations are most acceptable and most compatible with the local culture. Field-testing also provides experience in the search for local institutions that can most successfully operate solar systems. Although many of the projects are installed in equatorial Africa, new demonstration systems are now being planned in all regions of the Third World.

2.5.1 Educational TV System in Niger

In the early 1960s, the government of Niger (in conjunction with the French Ministère de la Coopération) began installing special solid-state D.C. televisions in remote rural areas to provide villagers with access to education and extension services. In 1968, the battery power unit of one system was replaced with photovoltaic cells. In 1972, after this experiment proved successful, the government began installing an additional 22 solar-cell-powered systems (out of a total of 214 units) [16, p. 201]. The photovoltaic arrays were produced by French and U.S. manufacturers and have functioned without serious problems. They proved to be cost competitive with the battery-powered systems when life-cycle costing is used.

2.5.2 UNICEF Village Appropriate Technology Demonstration

As part of a youth-training and manpower development program, the government of Kenya and the United Nations International Children's Emergency Fund (UNICEF) since 1976 have operated a number of renewable technologies in a demonstration village outside Nairobi. The exhibits include a solar crop dryer, hot water heater, and a wind power generator [17, p. 14].

2.5.3 Mali Renewable Resource Project

The USAID project outlined in Section 2.3.4 is designed not only to gather baseline data and to strengthen the Mali government's institutional capability to design, modify, build, and maintain solar systems, but also to install highly visible renewable energy systems for the rural population. In the first four months of this program, four photovoltaic pumps in the 1-2 kW range will be installed in three different locations in rural Mali [11, Appendix F]. One will provide irrigation and pure drinking water to new residents of the Samanko Leper Rehabilitation Village and will be used to train personnel from the Solar Energy Laboratory and the nearby School of Engineering. A second pump will produce water for a 5-hectare cooperative vegetable plot outside Mopti, while the remaining two will ensure water for human and animal use in Dilly, a community of 10,000 located 400 km north of the capital city. USAID explains that these "early start" systems are installed immediately for two reasons.

One is to provide a demonstration effect, to show that the project has as one of its main purposes the production, from solar energy, of goods and

services for use by the rural population. The second reason is to gain experience from the use of photovoltaic pumps under harsh climatic and physical conditions. [11, p. 2]

These demonstration pumps also will provide data on public acceptance and maintenance problems which will be incorporated into the third phase of the project, the installation of different solar technologies in as many as 20 villages (starting in late 1980).

2.5.4 The UNDP/World Bank Solar-Powered Pump Program*

In the next three years the United Nations Development Programme will sponsor four projects to demonstrate small-scale solar irrigation. The units will be installed in India, the Sudan, Upper Volta, and the Philippines, with management provided by the Energy Water and Telecommunications Department of the World Bank [18]. Although the final configurations and costs have not been determined, initial proposals called for one solar-thermal system (rated at 1 kW) and several micro-scale (0.25 kW) photovoltaic systems on each site, with a total budget of \$1.25 million.

2.5.5 SOFRETES Pumping Systems

The most commercially advanced solar products designed for Third World applications are the irrigation systems developed by the French consortium, SOFRETES. SOFRETES has installed pumps driven by flat-plate collectors and Rankine cycle engines since 1968. Originally conceived by the president of the Mengin pump company, SOFRETES today is a private firm with 71% ownership by the French government's Atomic Energy Commission, 25% by the partially government-owned oil company Compagnie Francaise des Petroles (CFP), with 2% participation by Anvar and Sofinova [19]. Although SOFRETES is a commercial firm, it is included in this section on assistance programs because it receives extensive financial and technical backing from the French government. The French government foreign assistance agency, FAC, also financed many of the installations, particularly in Africa.

By March 1978, more than 70 SOFRETES pumping systems had been installed in 18 Third World countries.** Fifteen of these 18 nations are in Africa or the Middle East, and most are located in former French Equatorial Africa. The largest SOFRETES installation was completed in San Luis de la Paz, Mexico, in 1975. This system provides drinking and irrigation water (150 m³/h or 25 ft³/min) for a community of 15,000, using 1,500 m² of collectors and a 40-hp pump drawing water from two 25-35 m wells [20, p. 1]. There were 17 SOFRETES installations in Mexico by the end of 1977, with many others in the planning stage.

A number of new departures will be marked in 1979 for SOFRETES as it develops and markets its solar-powered systems. As mentioned in Sec. 2.3.2, it will enter into a joint venture with ONERSOL, the Solar Energy Organization of Niger, to build and install a 5-kW and a 10 kW irrigation system. ONERSOL will locally manufacture the flat-plate collectors, and SOFRETES will provide the Rankine-cycle engine to convert the solar

*Much of this information was provided by World Bank staff members.

**Much of the data on number and location of installations were gathered from discussion with SOFRETES personnel and SOFRETES internal working papers.

heat to mechanical pumping power. Second, SOFRETES has decided not to market its systems in configurations smaller than 5 kW, since the smaller units proved to be too costly to produce, transport, and install. It will install several substantial irrigation systems in 1979, the largest in Bakel, Senegal, and Dire, Mali. The Bakel project will produce 30 kW of power for 10 hours a day. Funded by French assistance (50%) and USAID (50%), the 70-hp system is being developed and installed in conjunction with the U.S. firm, Thermal Electron. A 70-kW system is under construction in Dire, Mali. It will supply 8,000 m³/day of Niger River water to irrigate nearby fields. The SOFRETES system also will provide mechanical power to pump groundwater for drinking, as well as produce 20 kW of electrical power for lighting and cooling. SOFRETES will build an experimental solar-powered prototype electrical generating unit in Saudi Arabia, providing 35 kW peak power and 10 kW for 24 hours per day by using hot water storage. Third, SOFRETES is experimenting with extremely small-scale irrigation systems, based on mechanical principles used in the more than 2,000 man-powered systems that SOFRETES has already installed in Africa. In the new configurations, flat-plate collectors will heat and expand a working fluid that will be driven down into a well to expand a rubber bladder, thereby driving water up and out of the pipestem. Such units are limited to 8 m³/h but fortunately have no mechanical moving parts.

2.5.6 IDB/Dominican Republic Appropriate Technology Program

The Inter-American Development Bank (IDB) has funded the initial phase of an investigation into the application of "soft energy" technologies in rural settings in the Dominican Republic. These small-scale systems will range from flat-plate collectors for thermal power generation to water distillation units and solar cookers. This program will be coupled with a Dominican government program for the settlement of sparsely populated areas, much as the "Las Gaviotas" program was developed to assist newly transplanted settlers in Colombia.

2.5.7 Netherlands/TOOL Appropriate Technology Project, Indonesia*

From mid-1976 through 1979, the Ministry of Development Cooperation of the Netherlands provided more than \$1.5 million to the Dutch appropriate technology organization TOOL (Technische Ontwikkeling Ontwik-Kellingslanden: stitching tool), to develop and install, in collaboration with Indonesian villagers, a series of low-cost technologies. It included a simple solar bamboo and clear plastic dryer, a 120 litres/day solar hot water heater, and a hydraulic water ram pump. Several designs for biogas digesters were field-tested, and one large digester (16,000-litre capacity) and a cluster of four small digesters (total capacity of 1600 litres) were installed. A rice hull stove to provide heat for a rice dryer was installed and tested, along with a smaller rice hull stove designed for the kitchen.

2.5.8 USAID Office of Energy Program Area Demonstration

USAID's Office of Energy identified eight renewable resource areas in which it would like to encourage demonstration and research projects. Although the following list is not yet formally approved or matched with identified projects, it indicates the types of projects

*This information was provided by the Economics Section of the Royal Netherlands Embassy, Washington, D.C.

that may actively involve USAID in the next two to three years. The eight specific USAID objectives are:

- development of a field unit for the creation of nitrogen fertilizer by an electric arc process;
- provision of renewable energy systems to international voluntary organizations for their field stations;
- development of small-scale hydroelectric systems;
- photovoltaic systems for on-site water pumping and village level-refrigeration and cold storage;
- expansion of biomass production (increased yield per acre);
- development of more efficient boilers for converting wood and forestry by-products into electricity and process heat;
- deployment of small-scale, low-technology systems for converting wood and plant matter into alcohol; and
- installation of renewable energy systems designed to meet energy needs of island populations and coastal villages.

2.5.9 World Bank/Introduction of Efficient Wood-Burning Stoves, India

As part of a \$23 million forestry project approved in mid-1979 by the International Development Association, the World Bank will fund the construction of more efficient wood-burning stoves in the Indian province of Uttar Pradesh. Indian researchers will work with local forestry committees to introduce these designs in more than 1,000 villages in the next few years.

2.6 INTEGRATED ENERGY SELF-SUFFICIENT VILLAGES

Within the last three years, interest has arisen in the creation of "living laboratories," communities where baseline energy data collection, hardware equipment development and testing, and personnel training can occur simultaneously. These "solar villages" are usually designed to test renewable energy technologies, seeking combinations which can meet the basic energy needs of village life: cooking, irrigation, crop drying, refrigeration for medical supplies, communications, provision of potable drinking water, and lighting. These projects try to provide energy to an existing village or create a new community around the energy production facilities.

2.6.1 U.N. Environmental Programme Rural Energy Centres (UNEP)

The UNEP will create three Rural Energy Centres (REC): one in the Pattiyaapola area of Sri Lanka; one near Ndia Gorey, Senegal; and the third in Vallecitos de Zaragoza, Mexico. A fourth center is being considered for Pakistan. These three projects will follow the "all electric" approach long championed by Dr. Ishrad Usmani, who became the Senior Energy Advisor to the UNEP in 1975. They will focus on electrical power generation, using centralized photovoltaic arrays and complementary generating systems, battery storage, and other state-of-the-art manufactured systems. For example, the Sri

Lanka installation, when completed, will have four U.S. wind turbines producing 50 kWh, a flat-plate photovoltaic array, a concentrating solar thermal system, and an Indian 10-kWh biogas generator [21]. The proposed Mexican system will feature a 0.8-kW photovoltaic array for irrigation and a very large biogas generator (six linked reactors totaling over 200,000 litres) to provide 60 kW of electrical power, as well as gas for cooking. Backup power for the biogas-powered electrical generators will be provided by a small photovoltaic array and battery storage [22]. Each REC will cost over \$300,000 to build and will be tested for several years to determine costs and operating difficulties. Dr. Usmani envisions the creation of 1,000 such solar villages within the next 10 years, if the price of installed photovoltaic systems is brought down to \$3/Wp (it is \$15-\$25/Wp or more for remote site installations outside the United States).

2.6.2 The Crete Village

Under the joint sponsorship of the International Energy Agency (IEA) and the governments of Italy and Greece, an ambitious program is underway to create a new solar-powered community in the Franco-Castello plains of Crete. This town will house 3,000 residents and will be built around greenhouses, biomass conversion, and wind energy. The greenhouses will extend the growing season, primarily for olives. Agricultural refuse, including the olive pits, will be burned to produce heat and power. The initial planning stage for this 700,000 m² facility has been completed, and contracts have been let to begin the development and construction phase [23].

2.6.3 U.S./Saudi Arabian Solar Village

On 30 October 1978, representatives of the United States and Saudi Arabia signed a five-year agreement to each invest \$50 million to support solar energy by "joint research, development, and demonstration projects . . . exchange visits by specialist teams of individuals . . . and education exchange opportunities for training or study" [24].

As part of this comprehensive agreement, a solar system has been developed for Al-Uyaynah, a village of 2,000 persons located 50 km from the capital of Riyadh. A flat-plate photovoltaic system of 50 kW peak power will be installed in 1979, with another 300 kW to be added in 1980. Storage will be provided for this electrical generation system, and consideration is being given to using concentrating photovoltaic systems for later increments to the power system. SERI provides much of the technical assistance for system procurement and monitoring. Estimated expenses for the Saudi Arabian village are \$2 million in FY79 and an additional \$4 million in FY80, primarily for the photovoltaic arrays. Uses for this output may be lighting, refrigeration, air conditioning, telecommunications, irrigation pumping, and water desalination. As part of this program, an extensive effort will be made to document the impact of the introduction of this technology on the local villagers and to collect a wide variety of baseline data on energy usage patterns.

2.6.4 West German/Mexican Sonntlan Pilot Project

As part of a large \$16-22 million bilateral cooperative program in solar energy, administered by the Mexican Ministry of Public Works and the West German Ministry of Science and Technology, an integrated solar system is being developed for the small Mexican Pacific coastal fishing village of Las Barrancas. Plans call for a 3,000 m² solar collector field to provide 100 kW_e of power for the population of 250, to drive a

multistage desalination/distillation plant, and to power absorption refrigeration units and ice-making facilities. A 5-kW_e array of photovoltaic cells will generate power for water pumping, telecommunications, and educational equipment. This three-year project, jointly funded by the two cooperating governments, is scheduled for completion in late 1981 [25, 26].

2.7 MANPOWER TRAINING

The training of Third World officials has always been a major emphasis of both bilateral and multilateral development agencies. Energy planning, however, was never seen as a separate and legitimate discipline; instead, it was always peripheral to power systems engineering. Large-scale hydroelectric dams and fossil fuel electric power plants received most foreign assistance funding, and training was tailored accordingly. This emphasis is now changing. Energy management, including the development of small-scale decentralized renewable technologies, has become a discipline that attracts wide-scale attention from the development community. While this interest has resulted in only one or two major projects, training in energy planning and management soon will be a major component of most development programs. If the United States and the Organization of American States (OAS) programs described in the following section are successful and well-received, they may serve as models for subsequent training efforts, such as the U.N. University proposals outlined in Sec. 2.7.3.

2.7.1 Energy Management Training Program for Developing Countries

Under a grant from USAID, IER at the State University of New York and the National Center for the Analysis of Energy Systems at the Brookhaven National Laboratory jointly sponsor eight-week training programs for Third World government officials and others involved in energy planning in developing countries. The first session ran in the fall of 1978, and additional sessions for groups of 30 selected officials are planned for fall 1979 and spring 1980. The course will provide practical information and tools for LDC leaders interested in developing national energy plans. It covers topics ranging from energy analysis models and energy information systems to energy sector investment strategies (including the "capital, infrastructure, and institutional factors that influence investment decisions by international and commercial institutions" [27, pp. 4-5]). Participants also will have the opportunity to visit U.S. energy facilities and confer with energy officials of the U.S. government and multilateral donor institutions.

2.7.2 OAS/IEA Latin American Energy Analysis Seminar*

In December 1978 under joint sponsorship of OAS, Rockefeller Foundation, and Ford Foundation, the Institute for Energy Analysis (IEA) conducted a two-week training session in Oak Ridge, Tenn., for Latin American officials interested in energy-related issues. The topics ranged from energy modeling to new developments in solar energy, biomass systems, and energy conservation. Plans call for additional sessions to be held in the future, with the specific time and location of the training yet to be determined.

*Information is drawn from discussions with staff members of the Rockefeller Foundation and on material provided by the Institute of Energy Analysis.

2.7.3 United Nations University Natural Resources Programme

The Natural Resources Programme of the U.N. University (UNU/NRP) in Tokyo has initiated a number of study projects that may result in the creation of energy training centers. In conjunction with the UNDP and the Indian Department of Science and Technology, UNU/NRP is considering the formation of a National Institute for Energy Studies to provide training to energy planners from various Third World central governments. The Natural Resources Programme may establish a center for training in geothermal energy at the National Energy Authority of Iceland [28].

2.7.4 USAID/DTI Southern Africa Renewable Energy Workshops*

In the summer of 1978 as part of its project identification process, USAID dispatched a two-man team from the U.S.-based Domestic Technology Institute (DTI) to assess energy needs throughout rural areas of Lesotho, Botswana, and Swaziland. During its 90-day stay, the DTI team not only gathered information on renewable energy resource availability and needs (focusing particularly on the needs for water purification to kill intestinal parasites and for efficient mud stoves and biogas generators to replace scarce firewood for cooking), but conducted numerous training sessions and hardware fabrication workshops. They assisted in the installation of over 40 renewable energy units, including mud solar cookers, evaporative coolers, greenhouses, thermosyphon hot water heaters, batch water heaters, and biogas generators. More than 400 local citizens were trained in renewable energy technologies. At the end of the visit, a seven-day training session was held in Swaziland for 60 village leaders, community organizers, and central government officials from the three governments. As a result of the success of the training mission, the Bureau of African Affairs of USAID is now considering in these three countries a \$1.5 million pilot project to run rural training groups and to set up renewable energy centers throughout southern Africa.

2.7.5 OAS/CSC Workshop on Energy Accounting for the Caribbean

Under the sponsorship of OAS, the Commonwealth Science Council (CSC), The Office of Energy of Puerto Rico, and the Center for Energy and Environmental Research of the University of Puerto Rico (CEER), a major subregional meeting was held in San Juan, Puerto Rico, for delegates from 12 Caribbean nations in May 1979. The week-long session was designed both to provide training on energy analysis to government officials and to develop a format for the collection and dissemination of energy supply and demand information. Particular attention was paid to the need for gathering data on rural energy use and for consumption of nonconventional energy sources.

*Information is based on discussions with Malcolm Lilleywhite of the Domestic Technology Institute and with USAID Africa Bureau staff. For a published account of the DTI project identification trip, see Anderson's "Appropriate Technology in Africa" [29].

SECTION 3.0

AREAS FOR INCREASED DONOR COORDINATION AND INFORMATION EXCHANGE

As can be seen from the preceding text and from Appendix A, the number of donor-funded development projects for renewable energy sources has been expanding at an exponential rate in the last several years. Donors that have been active in the solar energy field (such as the UNDP, OAS, and the foreign assistance agencies of the United States, France, and the Netherlands) have recently redoubled their efforts. Major new institutional actors (the government of West Germany, the Inter-American Development Bank, and the Rockefeller Foundation) within the last year have demonstrated willingness to expand the use of renewable energy sources in the developing world. The U.N. Conference planned for 1981 is stimulating interest in other donor agencies. Yet, most of the projects that have resulted from these donor initiatives have been administered in isolation. There has been little sharing of knowledge. Duplicative equipment testing and baseline data collection has occurred. Mistakes in technology choice or in project design have been repeated by donor nations and by recipient countries. In some cases, valuable information has been collected but is not widely distributed. In other projects, no systematic effort has been made to monitor and record the performance of energy systems or to note the interaction of the project with the local, social, and cultural environment.

The effectiveness of the many funded projects would be greatly increased if donor agencies would agree to two concepts:

- coordination of renewable energy project design and administration, and
- exchange of the technical information generated by each project.

These two concepts are interdependent. Unless each project is designed so that useful and universally reproducible information is generated, there is little point to establish an information exchange network. Unless the information is widely shared, the incentive for the donor agency and a Third World government to engage in data collection, technology evaluation, and project assessment will be much smaller. Keeping this interdependence in mind, future potential donor cooperation is outlined briefly below.

3.1 COORDINATION OF PROJECT DESIGN AND ADMINISTRATION

The simplest level of cooperation among donors for the design of renewable energy projects would be an agreement to include the following elements in every system funded:

- baseline data collection—local energy-use patterns and the energy-resource availability;
- evaluation of the performance of the renewable energy technologies used in the project;
- an analysis of the external factors (environmental, social, cultural, etc.) which affect the performance of the energy system installed; and

- an estimate of the changes induced by the introduction of the renewable energy system.

This minimal information can be gathered relatively quickly, once its collection becomes a routine part of all project identification and project execution efforts. The collection of these data is useful even for single small installations within large programs not focused on energy.

After project design features are identified, donor agencies then could agree upon the information to be gathered for each design element and the amount of funding to be set aside for these additional elements. As an example of potential components of two specific design elements—baseline data collection and technology evaluation—a number of specific data elements have been included in Appendix B.

A universal commitment to a specified minimum level of funding for these new project elements will be important. It will ensure that the performance of the tasks becomes part of the internal operating procedure of each agency and that the tasks, in fact, are performed. Because projects vary widely in scale and duration of donor funding, the commitment should be to a minimum percentage of total project funding that is earmarked for evaluation and baseline data collection. Based on a review of the projects examined in this paper and on discussions with donor desk officers of the cost of information collection in the field, one would estimate that the range of minimum financial commitments is as follows:

- baseline data collection: 2%-4% of total funding, and
- technology evaluation: 4%-6% of total funding.

For example, a \$500,000 project to provide renewable energy sources for several villages would include a minimum of \$10,000-20,000 for gathering data on local energy use patterns and on local resources before the project begins (perhaps as part of the project identification process). An additional \$20,000-30,000 would be set aside to monitor the performance of the systems installed, the impacts of the physical and human environment on system use and durability, frequency of repair, etc. Field experience may indicate that there is a certain minimum expenditure to collect this minimal data, which may raise problems for the low-budget, self-help projects often funded by non-government organizations. In such cases, the total percentage cost of data collection and technology evaluation may be somewhat higher than 6%-10%.

Information gathered would be available to Third World nations and to other donors in a common format. Because of the diversity of foreign assistance projects using renewable energy sources and the variety of end-use needs for energy, it may be necessary to develop a series of universally accepted formats that are technology specific or end-use specific and that are flexible enough to accommodate the internal reporting procedures of different organizations.

3.2 JOINTLY SPONSORED PROJECTS

A second type of project coordination results from the pooling of donor resources and information through joint sponsorship of development projects. Such donor cooperation in renewable energy projects is already underway in certain geographical regions, such as the sub-Sahara through the Club du Sahel and in Central America through the

Organization of American States. The channeling of projects through regional organizations or through multidonor consortia can accelerate the sharing of information on technology performance and modification. Such joint projects also pool the expertise of Third World nations that are leaders in certain renewable energy technologies with the resources of both industrialized and other developing nations. Joint projects also encourage the participation of donors who have little experience in renewable energy technologies and are apprehensive about initiating such a project without outside assistance.

3.3 GEOGRAPHICAL OR FUNCTIONAL DIVISION OF LABOR

The most extreme form of donor coordination is a geographical or functional division of labor. To eliminate duplication, major donor agencies could agree to focus their renewable energy development assistance on particular technologies, certain geographical regions, or specific end-use applications of energy. For example, some donors would concentrate on the development of small-scale wind systems for rural applications, while others would specialize in small-scale photovoltaic arrays or parabolic trough concentrating collectors.

This is an unlikely development, at least among bilateral donors, for three reasons. First, the major industrial nations are interested in the promotion of export sales of their renewable energy systems. The developing world is seen as a potentially vast market for technologies that are currently not competitive with fossil fuels within the industrialized nations. Many analysts reason that export promotion of solar systems will help reduce balance of payments problems, create economies of scale within the domestic industry of the exporting nation (thus lowering prices to the domestic consumer), and accelerate research on materials and production procedures in the private sector. Export promotion is a key toward understanding foreign energy programs of leading donor nations, such as the United States, West Germany, and France, and it is likely to become crucial to the assistance programs in other countries, such as Japan and Switzerland. It is unlikely that any of these countries will agree to foregoing potential LDC markets for renewable energy systems by restricting its development assistance to a limited number of technologies. Such a division of effort is possible among multilateral donors and U.N. agencies since they are already organized around function areas or geographical regions. For example, FAO will probably lead any U.N. projects that involve fast-growing wood species for firewood or the combustion of lumber by-products.

Second, major donor countries are governed by geopolitical considerations that greatly influence their foreign assistance programs. Donors have large assistance programs in certain regions because of ties of tradition and language, such as the large French presence in Francophone Africa and the Dutch programs in Indonesia. A significant assistance program may be established because of military alliances or the strategic location of a developing country. There also may be national assistance in order to forestall the use of another source, as in the U.S. international energy development program that, in part, seeks to decrease the proliferation of nuclear fuel reprocessing systems. These efforts by world powers to maintain a political presence in a country or strategically important region make it unlikely that they would agree to a geographical limitation of their foreign assistance or to a functional specialization.

Third, foreign assistance programs have their own internal inertia. Agencies that serve a spectrum of client groups or currently have a universal mandate will resist an international division of labor. They will also oppose the intrusion of specialized

agencies into the development assistance field. These three factors will slow or block any large-scale international specialization in foreign assistance for renewable energy sources.

SECTION 4.0

RECOMMENDATIONS FOR FUTURE U.S. GOVERNMENT INITIATIVES

The United States is in a unique position to shape the direction of renewable energy activities of the foreign assistance community, Third World national governments, and private industry in both developed and developing nations. This power to influence policy choice is due to the interaction of three separate factors:

- the large size and geographical dispersion of the U.S. bilateral foreign assistance program;
- the informal but major role that the U.S. government plays in the determination of new initiatives for most of the multilateral lending agencies and large U.S.-based nongovernment organizations; and
- the large U.S. domestic program of research, development, and demonstration in all renewable energy technologies.

The size of the U.S. foreign assistance program immediately affects both recipient countries and other donor agencies; U.S. grants or loans for a particular development objective provide visibility to an issue, which stimulates interest in other potential recipients. U.S. participation also lends a certain legitimacy that may trigger loans in the issue area (such as renewable energy development) by previously uninvolved donors. This is reinforced by the important role that the United States plays in the decision making of multilateral donor agencies. While the U.S. government does not directly affect the process of project selection, it does influence the choice of new initiatives through its large financial participation. For example, U.S. government interest was crucial to the 1978 decision of the World Bank to begin funding exploration and development activities in oil and gas, an area that, until that time, was left to the private sector. Also, the United States has the largest national reservoir of technical expertise and design information on renewable energy technologies. United States foreign assistance endeavors can draw upon this skill in project design, technology modification, and project management. Because of this national research effort, decisions by U.S. agencies to emphasize one of the many alternative energy technologies will immediately affect the choices of other nations. The U.S. acceleration of research and development of mass production of photovoltaics has stimulated increased funding by other producers, ranging from Mexico and India to France and Japan, and has increased interest from potential Third World consumers of photovoltaic-powered systems.

There are three different types of initiatives that the United States government can undertake in the next several years to increase the understanding of the advantages and limitations of renewable energy resources within the foreign assistance community. The first group of options is drawn from Sec. 3.0. These are actions that support increased donor cooperation and information exchange in renewable energy projects. Second, the United States can launch broad policy initiatives within its own foreign assistance programs that will serve as models for other donors, while providing more information to U.S. decision makers for project design and technology modification. Third, the United States can select promising but neglected areas within the seven categories of donor activities identified in this report. Concentration in these areas could well provide rapid returns in knowledge and technology evaluation without duplicating the efforts of other donor organizations. Alternatively, the United States can adopt a program developed by another donor and apply it in other locations. In order to provide a clear division

between these different initiatives, they will be treated individually in the subsections that follow.

4.1 U.S. ACTIVITIES IN SUPPORT OF DONOR COORDINATION AND INFORMATION EXCHANGE

4.1.1 Adoption of Uniform Baseline Data Collection and Technology Evaluation for All U.S. Renewable Energy Projects

The United States could immediately assist Third World nations and other major donors by collecting for every project it funds baseline data on pre-existing energy usage patterns and on renewable energy resource availability. These data would be uniformly collected in a format determined in consultation with other major donors and with representatives of the Third World. In each project, 2%-4% of total funding would be earmarked for this activity, and the findings would be distributed worldwide to development planners and project officers. This unilateral U.S. commitment would not only provide useful information for the design of site-specific assistance projects, but also would serve as an example to other donors to take the same step. If integrated into the current project-paper phase (after a proposed project has been identified and given initial approval), baseline data collection would not seriously increase the length of time or the planning funds required to initiate a project.

Coupled with this pre-project data collection could be a continuous effort to monitor and evaluate the performance of the renewable energy technologies installed in each U.S. foreign assistance project. This information would be collected in a format that would be useful to technological specialists and also to development planners and project officers charged with selecting alternatives to meet development objectives. Thus, the evaluation would not only report on equipment reliability, component degradation, and system output, but also social acceptance of the technology, project use of locally scarce materials or skills, etc. A commitment of 4%-6% of the budget for each project would ensure a thorough evaluation and the results could be distributed to interested parties in the public and private sectors.

4.1.2 Creation of a Central Clearinghouse of Information on Renewable Energy Technology Performance in Third World Environments

The United States could greatly assist in the coordination of information on renewable energy sources by providing a mechanism for the collection, compilation, and distribution of available data. Initially, this could be a central data storage and retrieval system for information generated by its own foreign assistance projects and by those of other bilateral donors who cooperate in information sharing within the OECD. It could be housed in the newly approved Institute for Scientific and Technological Cooperation (ISTC) since it has a mandate to engage in such a broad-based endeavor. The cost for maintaining this facility would be shared with participating donors, while the information generated would be made available at no cost to those nations who qualify for foreign assistance. After its establishment, this information clearinghouse could be expanded to include knowledge from multilateral donors, domestic appropriate-technology institutions, Third World national research institutes, and specialized technology centers.

Such a centralized world center for renewable energy technology data would greatly assist development planners, but it would pose some problems that strictly U.S. internal efforts would not encounter. The two major difficulties would be comparability and validity of data. Ensuring data comparability would require data collection instruments that could cover a range of local conditions but that are specific enough to assist an organization on a particular project. These instruments should be compatible with existing data banks and energy models. Data systems might have to be created that are specific to particular regions or geographical areas. The question of data validity is a more intractable one. Information on system performance must be accurate and must report deficiencies and failures as well as successes. As long as one of the driving forces in many foreign assistance programs is market creation and export promotion, there will be a tendency not to report unflattering information on a commercially produced system from the donor country. This problem must be addressed at the beginning of any international information exchange if the results are to be meaningful.

4.2 GENERAL INITIATIVES WITHIN THE U.S. FOREIGN ASSISTANCE EFFORT

4.2.1 The Use of Quasi-Experimental Designs for Renewable Energy Projects

United States development assistance projects that use renewable energy sources suffer from two distinct design problems. The first is lack of knowledge about the potential for alternative renewable energy technologies to provide a certain type of work in a given setting. Second, there is a lack of understanding about the comparative impacts of different social and environmental influences on the success of any particular energy system installed within a development project. These two problems are not unique to renewable energy projects (or to U.S.-funded projects), but they do cause severe problems for project designers and desk officers because of minimal experience within most organizations with almost all renewable energy technologies. Country desk officers have very little information with which to judge whether a proposed energy technology is the best choice for a given end-use need in a particular setting.

To overcome these two problems, there is a strong need for development projects that are deliberately designed to provide information about comparative performance of systems or to isolate external factors that influence project success. Different energy technologies, both renewable and fossil-fueled, can be installed in parallel in the same or neighboring locations and used to perform the same work. These systems then would be exposed to the same environmental, social, and economic context and the same institutional limitations. The outputs of the systems, their durability, their maintenance requirements, and their compatibility with local customs and production could be measured then and directly compared. Unlike several of the solar villages under construction, such a project would not demonstrate a single technology or advance a single approach to development planning. It would, however, provide a controlled environment for measuring the efficiency of competing technologies for meeting development objectives in the field.

In order to provide information on the relative importance of individual external factors, identical energy systems can be installed in series in a number of settings that vary from one another in a controlled fashion. For example, a simple water pumping system could be installed in each of eight African villages that have highly similar economic and social structures. The projects would be identical except that three variables would be systematically altered:

- the method by which the proposed project is introduced (strong initial consultation with the villagers or little consultation);
- the maintenance of the operating system once it is installed (use of outside contractor or a trained local villager); and
- the distribution of the resulting water (communal tank or an allocation process determined by the local village leaders).

Combinations of these three variables would be used in each village to help determine which of these factors is crucial to the successful implementation of a water pumping project.

Quasi-experimental designs, such as the two just described, can provide much useful information to project designers and administrators in a short period of time. They can help to determine what factors influence project success or failure and to accelerate technology modification in order to meet local conditions. By building redundant systems into these designs or by installing a single system slightly differently in many similar locations, the project donor agency and the Third World government can jointly draw conclusions about optimal technology selection and project design.

Quasi-experimental designs have many advantages but also attendant difficulties. They tend to be larger projects and, hence, more expensive. They often involve unfamiliar concepts for both the donor agency's field personnel and the developing country's development ministry. Such difficulties, however, have been previously surmounted as the scope of development planning has broadened. Environmental concerns, impacts on migration, and changes in the role of women, for example, have been successfully incorporated into the planning of donor agencies and Third World governments. The additional costs that would accrue to the implementing U.S. agency (normally USAID), due to design considerations and to information collection, could be recovered. This recovery would be accomplished by cost-sharing with U.S. federal agencies (such as DOE) that need the information or with donor agencies (such as the World Bank) that gather data in order to inform their internal project review. The development of the initial project designs would require extensive discussions between U.S. foreign assistance officials and Third World leaders. They would locate governments that would participate in a more complex planning process in order to gain information that would greatly assist in the development of subsequent programs.

4.2.2 The Promotion of Joint Ventures between U.S. Firms and Third World Nations

The rapid expansion of U.S. foreign assistance and cooperative agreements in renewable energy sources will require the development and installation of many energy systems, ranging from photovoltaic-powered irrigation pumping systems and solar absorption chillers to simple thermosyphon water heaters. This will create a small but symbolically important market for producers of solar energy systems, one that will be actively pursued by both U.S. and Third World firms. The problem confronting U.S. foreign assistance planners is to find complete systems that are efficient, economical, durable, and easily maintained in a remote region. One solution might be to require that all bids to build renewable energy systems be a joint effort between a U.S. firm and a local firm or local laboratory. A U.S. company usually would provide or license the renewable energy source (windmill, photovoltaic array, small-scale hydroelectric turbine, etc.) while the local firm would assist in adapting the imported technology, provide the power-conditioning equipment, the system installation, and the required maintenance. Such an arrangement would have major advantages for all parties. For USAID, it would mean

that one crucial portion of the hardware, the power-conditioning equipment, had already been proven durable in the local environment. Spare parts and trained maintenance personnel also would be provided from the local firm's operations. For the local firm or laboratory, this arrangement offers experience with solar technologies, additional business, and information on what equipment modifications would be required to combine the system with the U.S. equipment. For the U.S. firm, a joint partnership would provide entry into a potentially lucrative foreign market, a preexisting repair facility, and a distribution network for future sales through the local firm. The U.S. firm would also receive from its local partner constant information on the design changes required to ensure durability, minimize maintenance, and increase social acceptance. Such an arrangement would foster the transfer of these technologies to the recipient country through the U.S. firm's access to new U.S. research developments and through the training of local counterpart personnel in system design and system sizing.

4.3 SPECIFIC INITIATIVES FOR U.S. FOREIGN ASSISTANCE

Areas that lack donor activity despite the demonstrated need have been identified in developing the survey that makes up the bulk of this report. Projects funded by non-U.S. donors that seemed to offer great promise for the acceleration of the development process also have been encountered. Projects of both categories are listed in outline form below according to the seven categories used earlier in this paper. When a particular project serves as a prototype, it is indicated in the text.

4.3.1 Baseline Data Gathering

4.3.1.1 Rural Energy Use and Availability in Latin America

There is a concerted effort by donors to assemble information on rural energy needs in sub-Saharan Africa and South Asia. A comparable endeavor is needed in Latin America, Central America, and the Caribbean. Because of Latin America's higher per capita income and relatively developed electrical grid, different approaches to the provision of energy may be required. Also, more information is needed on the social and environmental impacts of the use of traditional fuels in rural Latin American households. Such specific assessments should be undertaken also for island nations, such as those located in the Caribbean and the South Pacific.

4.3.1.2 Linking of Resource Assessments with Rural Energy Surveys

The international cooperative resource assessment programs that the U.S. government has undertaken with Egypt and Peru have provided to the leaders of those countries and U.S. foreign assistance officials a potentially valuable tool for the creation of long-term energy development plans. These resource assessments included a prediction of long-term energy demand, but only on an aggregated basis. The utility to project planners of these aggregate studies would be greatly increased if, as part of the resource assessment, a series of 5 to 10 detailed site-specific studies of rural energy use and availability is undertaken. This would allow the development and initiation of particular energy projects while the larger energy planning process was being completed.

4.3.2 Renewable Resource Creation and Management

4.3.2.1 Forest Waste Conversion to Electricity

The U.S. forest products industry has long been a leader in the provision of its own electricity and heat through the combustion of sawdust and wood by-products. The technology is proven and readily available. The UNDP project in Samoa indicates that wood-fired electric generators also can provide inexpensive power to communities near substantial logging or pulp industries. These lumbering facilities could serve as the nuclei for new communities or for the development of existing nearby villages.

4.3.2.2 The Development of a Charcoal Industry as Part of Existing Forestry Projects

The joint UNDP/FAO project in Ghana shows that forestry waste can be economically converted into charcoal and transported to more distant consumers. This is an alternative to the direct conversion of wood wastes to electricity when there is no preexisting wood-fired generating plant. The production of charcoal also helps meet the increasing need for cooking fuel, an area in which solar and wind systems thus far have been socially unacceptable or impractical.

4.3.3 Institution Building

4.3.3.1 Technology Transfer Networks

Foreign assistance organizations need to exchange practical information based on field experience. Designs for simple, durable, site-built energy systems can be exchanged and field-tested to determine their appropriateness for other locations. This transfer can take place through the recent U.N. initiative to promote technical cooperation among developing countries (TCDC) or through centers designed to facilitate such exchange, such as the VITA/PACT Documentation Center in Upper Volta or the Arusha Appropriate Technology Project. United States foreign assistance can foster a network of such centers by promoting the interchange of personnel and by providing institutional funds for the creation of additional units. A U.S.-sponsored technology evaluation clearinghouse, such as the one proposed for the ISTC in Sec. 4.1.2, can provide support for the collection and exchange of information among such regional or national centers.

4.3.3.2 Mobile Field Demonstration Teams

As was effectively shown by the work done by the Domestic Technology Institute in southern Africa, a small team of technicians trained in both renewable energy technologies and the technology transfer process can quickly promote the creation of many rural energy sources through "hands-on" workshops and demonstration projects. Such demonstration teams, initially composed of teams of local officials and USAID advisors can be set up in countries or regions. Over time, the local teams would become self-sustaining and could evolve into permanent small-scale rural research and training groups. The USAID advisors then could train groups in other regions or countries. Two such USAID advisory groups could train up to eight sets of local demonstration teams per year, while stimulating the installation of hundreds of renewable energy systems through the workshops.

4.3.4 Technology and Hardware Development

4.3.4.1 Efficient Wood-Burning Cook Stoves

There is a major need to promote the widespread adoption of simple, inexpensive stoves that drastically decrease the consumption of firewood for cooking. Although this need is most commonly voiced in the context of sub-Saharan Africa, it is also a significant problem in areas as widely dispersed as Nepal and Bolivia. These systems must be developed regionally because of the strong social customs and traditions that center on food preparation and because of variations in local fuels. Information-sharing will be particularly important in this field because a number of designs are already developed and are being tested throughout the world. Such promotional projects also could be linked to data collection, such as the World Bank projects in Mali and Burundi (see Sec. 2.1.1 above).

4.3.4.2 Simple Irrigation Pumps to Couple with Solar-Electric Sources

Much donor effort is being expended in the demonstration of renewable energy systems that produce electricity for water pumping. Although the major portion of the funding is allotted to photovoltaic projects, there also are systems that use wind power and even flat-plate solar collectors, as in the SOFRETES installations. There appears to be a significant potential for extremely small, low-lift systems (what Allison and Smith call micro-irrigation pumps [30]) if pumps small enough can be designed and mass-produced to couple with the solar power sources. Prototype pumps, such as the unit developed at the MIT-Lincoln Laboratory, have been designed, but there is now a need for extensive development of these experimental models.

4.3.5 Demonstration and Field Testing

4.3.5.1 Small-Scale Hydroelectric Generators

There are a number of commercially available low-head or run-of-the-river hydroelectric generators. There are also several low-cost experimental systems that have been developed by foreign assistance programs, such as the Swiss-funded systems in Nepal and the Las Gaviotas water turbines in Columbia. It would be useful to test a number of these commercial and experimental designs in remote locations, while studying the feasibility of underwriting one or more Third World manufacturing facilities.

4.3.5.2 Combined Water Treatment and Energy Production Facilities

Through the use of fast-growing aquatic plants, such as water hyacinth and duckweed, simple but effective water treatment and sewage treatment plants can be constructed. Prototype systems in the United States also can provide energy through the conversion of plant remains to methane gas. Such systems could be installed as parts of U.S.-funded integrated rural development projects, particularly in areas where the contamination of drinking water is a definite health hazard or where there is a major problem with water-borne parasites.

4.3.6 Integrated Energy Self-Sufficient Villages

There is no pressing need to initiate any "solar" villages within the U.S. foreign assistance program until the results from the existing villages sponsored by other donors are available. It might be wise, however, to begin the design phase of one or more villages that use a variety of technologies, rather than continue the current focus on a particular system or energy form (such as the UNEP all-electric approach). Detailed studies are needed also on the trade-off and energy loss when thermal and mechanical energy are converted into electricity rather than into direct usage.

4.3.7 Manpower Training

United States foreign assistance has always made a major commitment to the training of Third World officials. This effort is shifting to reflect the greater importance of energy in development planning today. More training sessions such as the Energy Management Training Program (Sec. 2.7.1) should be encouraged, because of the increased attention that energy planning, in general, and renewable energy sources, in particular, will receive in preparation for the 1981 U.N. Conference on New and Renewable Sources of Energy. These could be organized on a regional basis or in conjunction with one or more Third World national research organizations.

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APPENDIX A*

**CATALOG OF
FOREIGN ASSISTANCE PROGRAMS
USING RENEWABLE,
NONCONVENTIONAL ENERGY SOURCES****

*Much of the information on bilateral assistance programs is drawn from an International Energy Working paper, "Inventory on IEA Member Countries' Cooperation with LDCs in the Field of Renewable Energy Sources," November 1978.

**An effort has been made to eliminate all conventional large-scale hydroelectric projects from this catalog, but some components of such systems may be included inadvertently.

I. BILATERAL ASSISTANCE

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<u>Australia</u> (with India)	Regional South Pacific	Energy needs and small-scale energy possibilities	-
<u>Austria</u>	Egypt	Solar energy research center planned	-
	Egypt	Pump storage power station	590
	Malta	Solar energy test station	50
	Nepal	Small hydro power plant	-
	Upper Volta	Solar energy test station	54
	Upper Volta	Dev. and testing of solar cooker	20
	Yugoslavia	Solar cooling equipment tests planned	-
	UNIDO	Workshop on biomass conversion	77
<u>Belgium</u>	Burundi	Hydro-78	79
	Burundi	Hydro-79	592
	Cape Verde	Wind/Solar	-
	Egypt	Solar	-
	Mali	Hydro-78	-
	Rwanda	Biogas	269
		Solar	251
		Biogas (planned)	359
	Tanzania	Hydro-78-79	725
	Zaire	Solar power	-
	Zaire	Biogas	-
<u>Canada</u>	Benin (with Togo)	Mono River improvement	-
	Bolivia	Icla hydro study	4,220
	Bolivia	Afforestation research, firewood	150
	Botswana	Wind power/water pump field research	50
	Ecuador	hydro	-
	Egypt	Lower Aswan hydro study	-
	Egypt	Afforestation research, firewood	110
	Egypt	Solar dehydration of crops	100
	Ethiopia	Wind power/water pump field research	128
	Fiji	Rural energy studies	020
	Ghana	Afforestation research, firewood	150
	Haiti	Hydro resources study	-

BILATERAL ASSISTANCE (continued)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<u>Canada (cont'd)</u>	India	Kundah 4 hydro	1,330
	Indonesia	Tes hydro	1,010
	Jordan	Afforestation research, firewood	140
	Kenya	Afforestation research, firewood	170
	Laos	Nam Ngum hydro	2,140
	Lesotho	Hydro study	840
	Madagascar	Grand Rogez hydro	-
	Malawi		
	Mali	Afforestation research, firewood	160
	Nepal	Mini hydro study	-
	Niger	Barrage W., study	840
	Niger	Forestry	120
	Nigeria	Afforestation research, firewood	230
	Nigeria	Afforestation research, firewood	230
	Pakistan	Hydel Rankine study	500
	Peru	Afforestation research, firewood	250
	Senegal	Afforestation research, firewood	140
	Sudan	Afforestation research, firewood	140
	Tunisia	Afforestation research, firewood	180
	Zaire	Solar power	-
	Zaire	Charcoal stove improvement	-
	South & SE Asia	Economic and social constraints to biogas	50
	Asia, Africa, Latin Am.	Energy from aquatic biomass	80
	Asia	Rural energy tech. policy studies	380
<u>Denmark</u>	Kenya	Hydro	50
	Sudan	Solar	44
	Tanzania	Solar	35
<u>France</u>	Niger	Photovoltaic power for TV system	-
	Thailand	Renewable energy resources information center (financed with UNESCO)	
<u>Germany</u>	Afghanistan	Solar (planned)	142
	Argentina	Wind-Darrieus type	400
	Botswana	Wind power/water pump field research	40
	Brazil	Wind-horizontal turbine	280
	Cyprus	Prototype photovoltaic installation	50
	Egypt	Prototype photovoltaic installation	421

BILATERAL ASSISTANCE (continued)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<u>Germany (cont'd)</u>			
	Egypt	Solar	816
	Ghana	Solar	540
	Haiti	Wind	765
	India	10-kW solar power plant	-
	Iran	Solar	280
	Jordan	Solar	1,460
	Kenya	Solar	750
	Korea	Wind	60
	Korea	Hydro	120
	Malta	Wind	3,700
	Mexico	Drinking water by solar energy	1,600
	Mexico	Solar (planned)	11,900
	Nepal	Hydro	40
	Niger	Solar engine	170
	Paraguay	Biogas	1,420
	Peru	Mixed	2,830
	Peru	Solar	30
	Philippines	Solar/geothermal	4,570
	Senegal	Solar (planned)	3,400
	Sudan	Biogas	1,890
<u>Israel</u>			
	Mexico	OTEC (planned)	-
<u>Ireland</u>			
w/UNIDO	Rwanda	Exploration of peat deposits in Rwanda	-
	Burundi	Survey of peat deposits	8
	Tanzania	Survey on exploration of bogs (planned)	1
<u>Italy</u>			
	Bolivia	Geothermal	-
	Colombia	Geothermal	-
	Djibuti	Geothermal	-
	Egypt	Solar	-
	Ethiopia	Geothermal	-
	Philippines	Geothermal	-
<u>Japan</u>			
	Bolivia	Pilaya River feasibility study (planned)	-
	Chile	Feasibility study for geothermal power station	5
	Indonesia	Maung hydroelectric	-
	Malaysia	Lebir River power project (planned)	-
	Peru	Santa River feasibility study	220

BILATERAL ASSISTANCE (continued)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<u>Japan (cont'd)</u>	Philippines	Diduyon feasibility study	650
	Tunisia	Kasseb pumped storage feasibility ts.	240
	UNESCO	Group training project, geothermal	90
<u>Netherlands</u>	Egypt	Solar energy cells (planned)	280
	India	Windmills for irrigation	400
	Indonesia	Project on appropriate technology (solar dryers, biogas)	1,600
	Indonesia	Rural electricity, biogas	78
	Indonesia	Windmill, water turbines, etc., Flores	78
	Indonesia	Small-scale hydro study	-
	Lesotho	Solar water heating	-
	Sri Lanka	Windmill prototypes	130
	Sri Lanka	Solar ice production unit	26
	Tanzania	Gas generator fueled by agricultural waste	870
	Thailand	Solar thermal energy	-
	Upper Volta	Feasibility study, solar drying of nuts	-
	Upper Volta	Wind mills for water pumping (planned)	-
	North Yemen	Feasibility study on windpower for irrigation and drinking water	-
	5 countries	Windmill countries project	1,560
<u>New Zealand</u>	Fiji	Hydro (78-79)	-
	Fiji	Wind (78-79)	-
	Philippines	Geothermal	-
<u>Norway</u>	Nepal	Asst. for construction cy. for electric power	160
	Papua New Guinea	Feasibility study for rural elect.	845
	Philippines	Consultancy & feasibility study	1,000
	Tanzania	Feasibility study	6,000
<u>Sweden</u>	Bangladesh, India	Forestry with energy plantation	13,420
	Ethiopia	Forestry (fast-growing species)	11,500
	Tanzania	Forestry (fast-growing species)	21,080
	Tanzania	Appropriate technology center (includes renewable energy technologies)	-
	FAO	Village forestry program	-
<u>Switzerland</u>	Afghanistan	Solar energy for making cheese	100
	Bangladesh	Electric generation	3,700

BILATERAL ASSISTANCE (continued)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<u>Switzerland (cont'd)</u>			
	Bolivia	Solar energy for water purification	6
	Cape Verde	Research on wind, solar, and geothermal energy (with UNDP)	170
	Colombia	Energy research	20
	Costa Rica	Support of forestry services	200
	India	Solar pumps	-
	India	Conversion of cellulose for energy	100
	Lesotho	Solar energy for water purification	6
	Madagascar	Solar research	30
	Mali	Afforestation	-
	Nepal	Research center for applied science	100
	Nepal	Mixed technology studies	60
	Nepal	Biogas/solar studies	100
	Nepal	Micro-hydro study	660
	Pakistan	Afforestation	-
	Paraguay	Support of forestry services	860
	Peru	Solar energy for making cheese	1
	Peru	Support of forestry services	230
	Peru	Center for agriculture and forestry	1,190
	Rwanda	Electric transmission	7,940
	Tanzania	Solar and wind studies	20
	Thailand	High-tension power transmission	380
	Upper Volta	Afforestation	790
<u>United Kingdom</u>			
	Ecuador	Hydroelectric equipment	1,830
	India	Rock mechanics expertise for hydro	510
	Korea	Biogas	66
	Mauritius	Sea-wave measurements	80
	Pakistan	Prep. stage for Kalabagh Dam (planned)	-
	St. Lucia	Geothermal	1,648
	Sierra Leone	Solar	13
	Sri Lanka	Feasibility study—design stage	1,050
	Zambia	Turbines for Karfue Gorge and Victoria Falls	400
	6 countries	Wind studies	-
<u>United States</u>			
<u>A. Africa Region</u>			
	Lesotho	Alternative energy resources development	574

BILATERAL ASSISTANCE (continued)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<u>A. African Region (cont'd)</u>			
	Botswana	Alternative energy	580
	Botswana	Alternative energy	500
	Gambia	Gambia reforestation	338
	Swaziland	Alternative energy	446
	Mauritania	Renewable energy management	459
	Niger	Solar energy	-
	Niger	Niger forestry and land use planning	149
	Senegal	Bakel irrigated perimeter	700
	Senegal	Fuelwood production (greenbelt)	1,200
	Senegal	Renewable energy resources	500
	Upper Volta	Forestry education and development	700
	Mali	Action Ble	30
	Mali	Renewable energy	2,674
	Burundi	Alternative energy-Peat II	2,500
	Africa-wide	PDS-firewood study	400
	Africa-wide	PDS-feasibility studies	1,207
	Ghana	PDS (Ghana-pyrolitic converter)	83
	Burundi	AIP-Burundi	490
	Upper Volta	AIP-solar energy demo	80
	Benin	AIP-wood charcoal	56
	Africa-wide	Energy initiatives for Africa	1,100
<u>B. Asia Region</u>			
	Nepal	Rural area development Rapati Zone	700
	Nepal	Resource conservation and utilization	1,500
	Nepal	RAD/RCU design project	650
	Nepal	Radio education teacher trng	412
	Sri Lanka	Reforestation & watershed management	1,000
	India	Technology for the rural poor	3,330
	India	Rural energy	5,000
	Pakistan	Nonconventional energy	500
	Philippines	Nonconventional energy dev	8,650
	Thailand	Renewable/nonconv energy dev	5,000
	Indonesia	Science and tech-practical app for dev	270
	Indonesia	Appropriate and low-cost technology	125
	Indonesia	Energy manpower and training	1,000
	Region-wide	Energy development and support centers	2,145

BILATERAL ASSISTANCE (continued)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
C. Latin America and the Caribbean			
	Bolivia	Technical support PD+S	76
	Bolivia	Appr tech research and appl	600
	Costa Rica	Science & tech	1,000
	Dominican Republic	Natural resources management	3,000
	Dominican Republic	Energy assessment	250
	Region-wide	PD and S	90
	Haiti	Appropriate technology	399
	Haiti	Integrated resource management	454
	Haiti	Paraprofessional Eng training	112
	Panama	Special development activities	15
	Panama	Renewable energy sources	400
	Panama	Environmental management	200
	Peru	Appropriate rural technologies	240
	Jamaica	Project dev & support	205
	Jamaica	Science and technology	100
	Caribbean	PD&S	30
	Caribbean	Alternative energy systems	1,400
	ROCAP	Nonconventional energy studies grant	500
	Latin America	Energy research dev	125
D. Near East Region			
	Egypt	Tech transfer and manpower dev III	300
	Yemen	Appropriate village tech	1,070
	Region-wide	Energy	2,163
	Region-wide	Project design services	300
	Tunisia	Science and technology	275
E. Development Support Activities			
	Worldwide	Energy service and support	2,980
	Worldwide	Training energy and inst dev	2,800
	Worldwide	Energy asses, analysis, and policy dev	2,800
	Worldwide	Energy expansion through biomass	3,660
	Worldwide	Energy education and PVOS	2,350
	Worldwide	Applied energy tech/hydro	3,350
	Worldwide	Energy expansion thru solar	4,000
	Worldwide	LDC forest resources	750
	Worldwide	World Whiz	258
	Worldwide	Trop soils/BNF	250
	Worldwide	Trop soils/BNF	240

BILATERAL ASSISTANCE (concluded)

Donor Country	Recipient Country	Project Information	Funding (thousand \$US)
<hr/>			
		<u>E. Development Support Activities (cont'd)</u>	
	Worldwide	Trop soils/BNF	250
	Worldwide	Trop soils/BNF	240
	Worldwide	N-Fix res	120
	Worldwide	N-Fix lighting	500
	Worldwide	N-Fix symbiotic	2,056
	Worldwide	N-Fix nonsymbiotic-Florida	345
	Worldwide	Food and nutrition	25
	Worldwide	Wood as a fuel resource	250
		<u>F. Program and Policy Coordination</u>	
	Worldwide	Socioeconomic studies and activities	250

II. MULTILATERAL/REGIONAL AGENCIES

Institution	Recipient Country	Project Information	Funding (thousand \$US)
<u>World Bank</u>	Bolivia	Development of low-cost alternative energy hardware	165
	Burundi	Wood energy use survey	4,300
	Colombia	National rural energy dev plan	
	Costa Rica	Micro-hydroelectric generation and wind energy potential	500
	India	Introduction of more efficient wood-burning stoves in Uttar Pradesh	
	Israel	Solar ponds and Rankine cycle turbines	1,700
	Liberia	Demonstration projects-solar water heating	
	Mali	Wood energy use survey	4,500
<u>World Bank w/Switzerland</u>	Cape Verde Islands	Research on wind, solar, and geothermal	
<u>Interamerican Development Bank</u>	Costa Rica	Geothermal feasibility study	4,300
	Regional, Central America	Development and dissemination of appropriate energy technologies	650
	Dominican Republic	Applied investigation on solar technologies	
<u>OAS</u>	Brazil	Demonstration and commercialization of solar dryers for crops	
	Brazil	Selective surfaces	
	Brazil	Refrigeration for isolated rural areas	
	Guatemala	Village-level technology development	
	Jamaica	Refrigeration for village applications	
	Jamaica	Solar mapping	
	Jamaica	Small-scale crop drying	
	Mexico	Manufacture of silicon-photovoltaic cells	
	Mexico	Solar thermal equipment for refrigeration	
	Mexico	Solar mapping	
	Peru	Development of collectors with selective surfaces for use in industrial potash projects	
	Surinam	Small-scale (50kW) low-head hydro project for remote village	
	Trinidad/Tobago	Distillation of water	

MULTILATERAL/REGIONAL AGENCIES (concluded)

Institution	Recipient Country	Project Information	Funding (thousand \$US)
	Trinidad/Tobago	Crcp dryers for small farmers	
	Regional, Latin America	Latin America energy analysis seminar	
	Regional, Latin America	Seminar on utilization of biomass for energy production	
	Regional, Latin America	Workshop on energy accounting	

III. UN AGENCIES

Agency	Recipient Country	Project Information	Funding (thousand \$US)
<u>UN</u>			
	Greece	Solar energy	
<u>UNDP</u>			
	Afghanistan	Irrigation and power development	
w/Switzerland	India	Solar energy utilization in agriculture	
w/World Bank	India, Sudan, Upper Volta, Philippines	Demonstration of small-scale solar irrigation systems	1,250
w/UNIDO & UNESCO	Turkey	Establishment of solar energy research and development center	76
w/Netherlands	Colombia	Development and manufacture of low-cost appropriate technologies	800
w/Asian Development Bank	Korea	Institutional development for Korean Institute of Energy Conservation	848
w/UN Capital Dev Fund	Samoa	Electricity from wood wastes	1,631
w/UN	Pakistan	Rural energy center development	47
w/UNIDO	Philippines	Energy from biomass waste	400
w/UN	Thailand	National energy planning	300
	Mongolia	Rural development through use of water, wind, and solar energy	1,000
w/France	Niger	Solar energy program (development and fabrication of solar devices)	
w/FAO	Ghana	Forestry development/charcoal production	1,400
w/UN	Ecuador	Institutional support for solar energy and biogas activities	180
w/Netherlands	Colombia	Development and manufacture of low-cost appropriate technologies	800
	Jamaica	Survey of alternative energy/sources	
<u>UNDP</u>			
w/UNESCO	Mexico	Photovoltaic research and production of PV-powered pumps	381
w/UNESCO and SOFRETES	Mexico	Development and manufacture of solar-thermal electric engines for water pumping	381
	Regional Africa	Solar energy	
w/WMO	Regional Africa	Sub-Sahara solar insolation data project	
	Regional Latin America	Alternative energy resources and production capability	

III. UN AGENCIES (concluded)

Agency	Recipient Country	Project Information	Funding (thousand \$US)
<u>UNEP</u>	Sri Lanka, Senegal, Mexico	Electric power generation from renewable energy resources	900
<u>UNESCO</u>	Algeria	Development of solar energy applications	
<u>UNIDO</u>	Cyprus	Solar salt plant (site evaluation)	
	Egypt	Solar stills (consultation)	
	Kenya	Wind-powered water pumping, feasibility of manufacture	
	Panama	Solar salt production, exploratory	

IV. PRIVATE FOUNDATIONS/VOLUNTEER ORGANIZATIONS

Organization	Recipient Country	Project Information
<u>Rockefeller</u>	Dominican Republic	Conference on energy and agriculture in the Caribbean, also specific energy studies in the Dominican Republic
w/East-West Center	Regional, Asia	Testing of solar-powered nitrogen fertilizer production
<u>al Dir'iyyah</u>		
w/IER, Stay Brook w/U.S. Peace Corps	Worldwide	Energy Information System for LDCs
w/UNDP	20-30 countries	Data collection project
w/UNDP	Worldwide	Local-level energy data collection
w/UNDP	India	Demonstration projects
w/UNDP	Mali	Demonstration projects
w/UNDP	Philippines	Demonstration projects
<u>VITA</u>		
	Upper Volta	Clearinghouse for information on appropriate technology
	Papua New Guinea	Small-scale hydroelectricity
<u>Companeros de las Americas</u>	Nicaragua	Photovoltaic demonstration project

APPENDIX B***TECHNOLOGY EVALUATION FOR
RENEWABLE ENERGY SOURCES:
A FRAMEWORK FOR COORDINATED ACTION**

*This appendix is adapted from a report by John H. Ashworth and Richard E. Meunier, "Technology Evaluation for Renewable Energy Sources: A Framework for Coordinated Action," SERI internal working paper, March 1979.

SECTION 1.0

INTRODUCTION

Technology evaluation, a decision-making tool, allows the interchange of information among groups or government agencies working in the same field. This information exchange is particularly important for new experimental systems (such as renewable energy technologies) since both the technologies and the method of introducing them are undergoing rapid and constant modification.

Technology evaluation can either be planned as an integral part of the development of a project (prospective evaluation) or it can be begun after a system is installed and operating (reprospective evaluation). For a complete definition of technology evaluation and for a description of the differences among the alternative evaluation designs, see Appendix A. Technology evaluation, a subcomponent of a larger project evaluation, cannot be taken in isolation. The performance of equipment or of an entire system can only be measured and analyzed against defined needs or project objectives.

SERIO

SECTION 2.0

THE UTILITY OF TECHNOLOGY EVALUATION TO FOREIGN ASSISTANCE DECISION MAKERS AND TO THIRD WORLD NATIONAL DEVELOPMENT PLANNERS

2.1 GENERAL CONSIDERATIONS

Well-designed technology evaluation can assist in development projects, aid in the choice among alternative technologies, indicate the modifications required in technologies to meet specific end-use needs or local climatic conditions, and direct research and development funds to the solution of system deficiencies before reintroduction of the technology. If the evaluation is first planned as integral to the project, it also provides the decision maker with information for midproject corrections. Alterations can be made to a system, or new systems can be inserted into an ongoing project to improve performance. Experimental or quasi-experimental designs can be used, allowing for the control of extraneous variables so that the impact of the technology on the society or on project success can be carefully measured. If technology evaluation were practiced by donor agencies on a universal basis, it would vastly reduce duplication of effort, facilitate information exchange, reduce the possibility that inappropriate technology selection would occur during project design, and accelerate the process of technology adaptation and diffusion.

2.2 CONSIDERATIONS SPECIFIC TO RENEWABLE ENERGY SOURCES

Technology evaluation of renewable energy sources will provide decision makers with valuable information about areas that present uncertainties for project planners.

- Sizing—there is little available knowledge on the size of systems needed to provide basic energy needs for rural consumers, particularly when the new technology is replacing noncommercial fuels (for which consumption data are usually scanty or nonexistent).
- Coupling with energy conversion devices—technology evaluation can provide valuable information about the "fit" between an energy source and the machines or devices that will turn the energy output into useful work. This is particularly crucial where the coupling is experimental or relatively untried (low Btu biogas with refrigeration or cooling units, solar ponds with Rankine cycle electric generators, etc.).
- Component degradation—particularly important in the technology evaluation process will be the identification of components or materials of renewable energy systems that are rapidly degraded by extremes of climate and surroundings (i.e., wind-driven sand, high humidity, rapid growths of fungi and algae). This identification process will speed the technology modification process and identify areas for additional research and development.
- Induced social response—crucial for the technology evaluation of a renewable energy system is the determination of the change that it will trigger in local energy consumption and usage patterns. An understanding of this demand shift will help to analyze the ability of the new energy technology to meet certain objectives, particularly those that revolve around the rapid reduction of the consumption of traditional fuels (firewood, dung, and agricultural residue).

- Institutional change—the introduction of new energy sources will alter the actions and perceptions of preexisting institutions and may require the formation of new organizations. A comprehensive technology evaluation will provide decision makers with information on the amount of institutional change and adaptation that a particular energy system requires in a specific setting.

SECTION 3.0

ELEMENTS OF A TECHNOLOGY EVALUATION

The following outline of technology evaluation elements will focus on those evaluations that are planned and executed as integral to the project. This will provide the range of program elements; a retrospective evaluation would not require the sections on preexisting energy usage patterns and preexisting basic needs.

3.1 ENERGY USAGE PATTERNS

Prior to the inception of the project, locally available resources and the pattern of the use of these resources should be identified. An outline of the type of data on energy usage is contained in Appendix C.

This information will be useful to national decision makers and to project evaluators in three ways:

- it will provide a baseline against which the impacts of the project and the introduction of specific energy technologies can be measured;
- it will assist in the selection of technologies appropriate for local consumption patterns and available renewable resources; and
- it will indicate what basic development requirements have to be met by the project; this will provide some external criteria against which the success of the project and the performance of the technology can be analyzed.

3.2 BASIC NEEDS AND CURRENT CONSUMPTION

Energy at the village level is used to provide basic human services: housing; food production, processing, and preparation; water for human and animal consumption; health care services; and transportation. The availability of energy also affects settlement patterns, migration, employment practices, income distribution, and other social variables. Data on these indicators for local development and services should be collected before, during, and after the completion of the project.

3.3 TECHNOLOGY CHARACTERIZATION CRITERIA

It is extremely difficult, and often misleading, to generalize across renewable energy systems and to impose uniform evaluation criteria applicable to all technologies and all implementation settings. Specific evaluation criteria are needed for each renewable energy technology to determine if it will contribute toward the achievement of overall project objectives.

There are, however, analytic points that serve as a framework within which technology-specific evaluation criteria could be developed. These are presented in outline form, with notations of what factors should be included in the analysis. It should be noted that the last two sections, Social Compatibility and Environmental Constraints, are location specific and can be developed for a technology only within the context of a particular region or village.

- **Cost**
 - Initial capital cost (equipment purchase, energy conversion devices, power conditioning equipment)
 - Capital replacement (if portions of the system are expected to require replacement before the end of the project)
 - Transportation and installation
 - Local labor requirements for installation
 - Annual operating costs and maintenance
- **Benefits**
 - Economic (value of energy created, new local industries formed, capture of energy expenditure at local level, jobs created, etc.)
 - Environmental (eased pressure on local resources, enhanced standards for local health and sanitation, more efficient use of agricultural resources, etc.)
 - Social (substitution of mechanical power for human labor)
- **System Efficiency**
 - Cost per unit of energy output (e.g., \$/million Btu or \$/metric ton coal equivalent)
 - Cost per unit of work performed (e.g., \$/l of pumped water/hour)
- **Energy Delivered**
 - Form—electricity, shaft power, combustible fuel, etc.
 - Compatibility of form with identified end-use needs
 - Quantity—maximum and average output/unit time (peak and average watts, cubic meters of gas per hour, etc.)
 - Daily output variations
 - Seasonal output variations
- **System Characteristics**
 - Durability of materials and components
 - Longevity of system (expected lifetime with routine maintenance and planned equipment replacement)
 - Operation and maintenance (includes downtime for maintenance and planned equipment replacement, skills, and specialized equipment required for maintenance)
 - Reduction of output due to maintenance and parts replacement
 - Modularity—the ease with which the output of the system can be increased through the addition of more generating units
 - Compatibility of output with other energy systems (ability to tap into or feed output into an existing grid)
 - Multiple uses of output—how readily can the system switch from one end-use need to another due to changing consumption patterns and daily or seasonal swings in demand?

- **Social Compatability**
 - Aesthetics—does it cohere with local architecture and is it an attractive energy system?
 - Cultural and religious restrictions—these may influence when and for what purpose output can be used
 - Division of labor—will the introduction of a new energy technology alter the allocation of work by age and sex?
 - Local institutions—will the technology be appropriate for the political and social institutions? What changes would be necessary?
- **Environmental Constraints**
 - Wind, periodic storms, and wind-blown sand
 - Temperature fluctuations (requirements for venting and/or freeze protection)
 - Humidity, rain levels, and ground saturation (all affect materials durability, system performance, and natural required support structures)
 - Local animal and plant problems (borers, termites, algae, etc.)
 - Land-use requirements (removal of land from other uses, degradation of land for multiple uses)

APPENDIX C*

ENERGY USAGE PATTERNS

*Appendix C is taken from a report by John H. Ashworth and Richard E. Meunier, "Technology Evaluation for Renewable Energy Sources: A Framework for Coordinated Action," SERI internal working paper, March 1979.

SECTION 1.0

ENERGY SERVICES

This is an outline of elements that should be included in an initial, rural energy survey for a renewable energy project.

What are the present energy-consuming tasks? What are the sources of energy for these tasks?

Example: Basic energy needs and present sources

- Agricultural
 - Soil preparation (e.g., oxen)
 - Planting (e.g., by hand)
 - Fertilizing (e.g., manure)
 - Irrigating (e.g., electric pumps)
 - Harvesting (e.g., by hand)
 - Threshing (e.g., electric machine)
 - Grinding (e.g., windmill)
 - Preserving (e.g., sun drying)
- Household
 - Cooking (e.g., wood)
 - Potable water (e.g., water trucks)
 - Space conditioning (e.g., none)
 - Water heating (e.g., wood)
 - Lighting (e.g., kerosene lamp)
 - Communication (e.g., radio, phones)
- Travel
 - Hauling (e.g., cart)
 - Travel out of village (e.g., foot)
- Industrial
 - Home construction (e.g., by hand)
 - Village importing-exporting (e.g., truck)
- Public Services
 - Water pumping (e.g., diesel engine)
 - Communications (e.g., diesel generator)

SECTION 2.0

ENERGY BUDGET

- How much energy does each task require? Need to choose a measure that is applicable to all tasks—Btu, Kcal?
- Distribution: which task consumes the most energy? Percentage of total village energy consumption; percentage of total household consumption, percentage by sector.
- What is the relationship between the village environment and the level of fuel use?
- What is the frequency of each energy-consuming task? How reliable must the energy source be to meet the requirements of the traditional energy service?

SECTION 3.0

INCOME EFFECTS

What is the relationship between energy consumption and standard of living?

- Does choice of fuel for accomplishment of a task vary among income groups (e.g., do the wealthy use charcoal, the poor dung)?
- Do higher income groups use more energy per task?
- Do levels of efficiency of fuel use vary with income group?

SECTION 4.0

TASK PERFORMANCE

- Who performs each task? percentage of men; percentage of women; percentage of children; percentage of animal?
- Do these allocations of tasks change by season, income level, sector of employment, etc.?
- Are there traditions related to each task that affect or influence energy usage patterns (e.g., African women must cook grains separately for religious reasons)?

SECTION 5.0

ENERGY SUBSTITUTION

What is the interaction among varieties of fuels?

- What are the predominant sources of energy for each sector (e.g., in many Indian villages, human and animal sources provide 90% of agricultural labor)?
- What are the available substitutes under present conditions? Under what conditions are alternative sources used (e.g., income effects, fuel shortages, seasonality)? What are the costs, dislocations, duration of substituting for the traditional energy sources for various tasks?