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RURAL DEVELOPMENT:

Energy Constraints, Alternatives, and Opportunities

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Working Draft
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RENEWABLE ENERGY APPLICATIONS AND TRAINING PROJECT

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INTRODUCTION

Rural development efforts are intended to improve access to resources and services such as water, food, health care, education, shelter and economic opportunity. Fundamental to these efforts is the availability of basic infrastructure, human skills, financial capital and other resources for productive activity. Viable rural development is particularly dependent on the effective use of indigenous resources by the private sector for production equipment, raw materials, and as energy sources. Availability of electricity, for example, can stimulate agriculture and rural commerce and industry and help bring about fundamental improvements in the standard of living by improving communications and educational opportunities.

Unavailable or unreliable supply of energy can also have a serious impact on rural agricultural production and income. For example, it is reported that in the Sudan in 1984 some $100 million (U.S.) in agricultural output was lost due to shortage of energy supplies for irrigation and tillage. In Somalia lack of diesel fuel was reported to have reduced irrigated crop output by 40 to 60% in the same year.[1]

Substantial room still remains for development of energy resources, both renewable and more conventional oil-based technologies, to stimulate private sector activity and development in rural areas. In support of mission efforts, the Office of Energy (S&T/EY) is placing a high priority on assistance to increase the utilization of locally available energy sources (e.g. biomass, small-hydro, solar, wind), as well as provide access to electricity. Support to the local private sector and privatization are the primary strategies to ensure delivery of renewable and other energy sources for rural areas.

POTENTIAL NEXT STEPS TO ADDRESS ENERGY REQUIREMENTS FOR RURAL DEVELOPMENT

In order to effectively address the energy and other input needs for rural development, a combination of actions is

[1]Office of Energy, Small Power Systems for Economic Development in Rural Areas, October 1986.

required. Many of these are directly or indirectly related to the local private sector. Traditional development project intervention is not likely to be effective since large numbers of small private firms, communities, and farmers must be involved in rural development schemes. The most efficient strategy appears to be a combination of:

- o Policy reform
- o Credit programs
- o Technical assistance
- o Management assistance
- o Marketing assistance
- o Expanded supply of infrastructure[2]

Energy related assistance can be an important complement to the above elements of a private enterprise/rural development strategy, for example:

1. to <u>policy reform</u> by evaluating pricing policy for fuels, including tariffs and taxes, and distribution and levels of supply to rural areas;

2. to formulation of <u>credit programs</u> by developing project review criteria having to do with energy costs, requirements and alternatives;

3. to <u>technical assistance</u> by helping to establish local manufacturing, service and marketing of energy supply and utilization equipment;

4. to expanded <u>infrastructure</u> supply by identifying least-cost fuel sources and technologies to provide electric power or other energy requirements, designing energy supply projects, and providing information on successful approaches and technology applications from A.I.D. or other experience elsewhere. (see last page for proposed initiatives)

The following describes the more important rural economic activities, stressing those for which energy availability, cost, and reliability are likely to be an important consideration.

ENERGY SOURCES FOR RURAL APPLICATIONS

Energy resources and technology are important for a wide range of private sector agricultural and small industrial, as well as public service purposes. These include biomass and diesel combustion for agricultural drying, hydro power for mechanical or electric milling, electricity from a variety of

[2]Carl Liedholm, "The Private Sector Connection to Development," MSU International Development Paper, 1986.

alternatives for processing, storage and refrigeration, and diesel for harvesting, cultivation, and planting. In Africa, certain small-scale industries such as clothing and textiles, carpentry, and metal working are major sources of employment, and while energy use is small, it is often a vital ingredient. Table 1 summarizes some of the more significant rural industrial and public service functions where energy is an important ingredient.

Choice of Fuel and Energy Technology

The choice of technology for providing energy in private sector activities is often equally as important to the viability of a new venture as the type of production equipment and needed raw material. The purpose of introducing new energy supply technology is often to produce one or more of the following benefits:

- Improved productivity, e.g. increased yield per unit input of labor, energy or raw material.
- Improved quality of product with a greater profitability, e.g., higher quality milled grain or fired bricks.
- Substitution of less-costly inputs, e.g., water power or wood for diesel fuel in electric power production or drying.
- Production of a new product, e.g., ice for refrigeration or fabricated metal agricultural spare parts.[3]

The choice of technology should be governed by a number of factors which together determine the type, size, and fuel choice for new energy supply or utilization equipment. These factors include:

- current availability and cost of equipment and fuel;
- reliability of fuel supply;
- energy using equipment availability in size and configuration required;
- availability of local service and spares;
- potential for fuel or spares price increases, and/or sustainability of supply;

[3]John H. Arnold, Jr., Report on Rural Industries, A.I.D., October 1980.

TABLE 1. ENERGY RESOURCES AND EXAMPLE OF THEIR RESPECTIVE APPLICATIONS FOR RURAL AREAS

		Applications							
		Electric Generation	Milling	Brick-making/ Drying	Refrigerated Storage/ Ice-Making	Water Supply & Irriga-tion	Communications	Cooking	Lighting
Diesel/Other Petroleum Products		X	X	X		X	X		X
Biomass (e.g., wood, bagasse, coconuts shell husk, coffee grounds, etc.)		X	X	X	X			X	
Wind		X	X		X	X			X
Solar	Thermal			X					
	PV	X			X	X	X		X
Hydro		X	X		X	X			X
Geothermal		X		X					

- in-country experience with technology, and reports of present users;
- compatibility with the skill levels of production staff;
- capability for local manufacture.

RURAL DEVELOPMENT INDUSTRIAL, PUBLIC SERVICE, HOUSEHOLD ACTIVITIES, AND ENERGY REQUIREMENTS

Agro-processing

Many crops require processing after harvest to either improve storage characteristics or to enhance the value of the product to suit consumer/market requirements. Some of the more important rural production applications are described below.

Drying. In most countries, grain is dried through simple exposure to the sun, either in the field or on a drying pad. However, when harvest occurs during a wet season, mechanical drying becomes necessary to insure that losses due to spoilage are minimized. This can be accomplished using conventional fuels (e.g., kerosene or diesel) or by using biomass fuels. Experience has shown that solar dryers are often less effective than other alternatives, mostly due to the fact that the demand occurs during periods of low solar insolation. However, agricultural residues have been used quite effectively to provide the thermal energy for drying purposes.

Milling and Grinding. Small mills vary from larger commercial facilities in capacity and usually milling efficiency, but specific energy required is equivalent for most mills. Energy used in grain mills has been provided by small water turbines, electric motors, or by diesel engines. In some applications, such as sugar mills, steam systems have been employed to provide shaft power for the mill and to provide electricity to drive other auxiliary loads. Wherever and whenever available, hydro resources have been used to provide shaft power for grinding and milling.

Opportunities to expand the use of biomass fuels and hydro facilities to power mechanical loads exist in many developing countries. In many cases, this requires matching a suitably sized technology to a specific application. For example, by far the greatest number of rice mills are very small scale, requiring 5 kW prime movers to supply shaft power. A significant number of larger mills (25-200 kW) in use are presently powered by grid-powered electric motors or direct diesel drives. A very small

fraction of mills exist in the large category (over 500 kW). However, commercially proven biomass conversion systems are available for only very large systems. Systems in the small and intermediate ranges are available from limited sources and, by and large, have yet to prove themselves under continual field use. There is a need to develop biomass conversion systems capable of operating under adverse field conditions in the small and intermediate size range.

Food Processing

Rural enterprises usually have relatively few uses for thermal energy. Some of these present attractive opportunities for the conversion of renewable energy forms to service these thermal loads. The two major opportunities to exploit renewable resources in using these processes appear to be in food processing and the building materials industry.

Various important food processing activities are able to make use of renewable sources, including biomass and small-hydro. Canning plants consume vast quantities of steam in the processes of sterilization, pasteurization, and the bottling process itself. Ice making is very important in areas where fishing is a major industry. Very often, these areas are located far from population centers where the larger markets exist. In order to preserve the catch to insure quality upon delivery, the fish must be iced at the landing point or on the vessel itself. Refrigeration is also necessary in areas with dairy, table vegetable, or cut flower industries. With the introduction of smaller biomass-fueled absorption refrigeration equipment and in smaller applications, through the use of wind and photovoltaic-electric technologies, these loads can be met through use of renewables.

Building Materials. Ceramic kilns require continual high grade thermal input to maintain temperatures during the firing process. Brick making requires thermal energy to fire the clay. Lumber must be dried after milling, and production of plywood consumes large quantities of process steam. All these processes can and, in some cases, are being satisfied with biomass conversion systems. Some of them, if large enough to justify the capital expenditure, could be met by use of low temperature geothermal energy. In larger plant sites, some of these loads might be serviced by biomass-powered cogeneration systems.

Public Services

Water. Water is necessary for household purposes, agricultural production, health services, and also for some processes such as refrigeration (ice is often used for the preservation of seafood). Water lifting and pumping is an energy intensive process, and if large quantities are pumped,

conventional fuels will usually be required. However, for village or small enterpris' activities photovoltaics and wind can and have been used to service demands of 10-20 m^3/day and 10-50 m^3/day, respectively. Photovoltaics have been used to provide water supply for villages with remote water services. In most cases, when water is available on site, manually operated hand pumps are used to deliver water to a central distribution point. Wind driven pumps have been employed in some locations which have acceptable wind regimes and are meeting the demand for potable water and livestock watering. These systems, however, require relatively large capital outlays for appropriately sized equipment, which often is beyond the reach of a single user.

Health. Rural health clinics provide primary care to rural populations which do not have ready access to hospitals and medical technicians. While not private sector activity, rural health care is vital to maintain a stable and healthy labor force. These primary care facilities require electric and thermal energy for refrigeration equipment, lighting, and in some cases, sterilization equipment.

Refrigeration is required to extend the shelf life of vaccines and medicinal supplies. It may also be required to extend the life of specimens for laboratory analysis to be performed in more sophisticated medical centers located in urban areas. Refrigeration demands can be met by photovoltaic arrays with battery back-up units. Photovoltaic arrays can also be used to service lighting demands. These power requirements are relatively small (less than 1 kW), but are of a very high social value.

Thermal energy is needed to provide hot water for sterilization and cleaning other supplies and instruments. This may be provided by using solar thermal collector systems or by using a biomass fueled-combustion system. Typical fuels for combustion systems would include fuelwood or an agricultural residue, such as coconut shell, rice husks or perhaps corn cobs.

Household Uses

Traditional energy resources are used extensively in most countries to satisfy needs for cooking and household space heating. Food preservation, including both drying, and in some cases refrigeration, can also be satisfied by renewable resources. Most agricultural and home drying practices are accomplished by direct solar drying techniques (most often performed pre-harvest). In some cases when higher grade thermal requirements are necessary, agricultural residues or fuelwood may be employed.

Energy use for domestic cooking constitutes the major demand for declining traditional resources such as fuelwood.

Inefficient fuelwood use contributes to scarcity affecting rural commercial uses of woodfuel, as well as contributing to loss of water catchment areas and agricultural topsoil through erosion. Estimates in various countries suggest that cooking consumes from 62 to 80 per cent of total energy used in rural areas.[4] One major attempt to apply simple renewable technology has been the improvement in the efficiency of cooking devices. These have been promoted successfully in the case of commercial fuels such as charcoal, but this success has not been replicated in reducing the use of user-gathered wood or other biomass. Neither fuel substitutes such as briquetted biomass nor conservation are likely to have major impacts except where fuels are commercial. Household stoves and fuel substitutes in such cases often provide business opportunities for micro- or small enterprise.

ALTERNATIVE SOURCES OF ENERGY FOR RURAL DEVELOPMENT

Rural areas are at a severe disadvantage in terms of many of the critical inputs for economic development. Electricity, for example, has often been a critical input to production processes and small-scale commercial industrial activity. However, electricity is both particularly capital intensive and expensive to be provided by conventional grid extension to rural areas. Due to both the frequent problems remoteness and the lack of infrastructure, as well as the high cost of both oil products and electricity supply, rural areas need alternatives to the common energy solutions used for urban areas.

A great deal of attention has been given to renewable and appropriate energy technology application in recent years in an attempt to better address the needs of rural areas. A great deal has been learned about the successful application of renewable energy technology, and technology has improved. Nonetheless, conventional energy alternatives still often prove to be the most cost-effective and feasible options for developing countries. The technology and economic status of some of the major renewables are presented in Table 2 below.

Conventional Energy Alternatives

Notwithstanding the potential benefits of renewables, conventional energy sources will remain the appropriate choices for many rural development applications. Several conventional energy technologies relevant to rural applications are described in Table 3 below. These include diesel and gasoline electric generators, and oil and wood fired combustion equipment for generation of steam or process heat for drying.

[4]Revelle, 1976, and Walton, 1978.

TABLE 2 SUMMARY OF TECHNOLOGY STATUS AND APPLICATIONS

PHOTOVOLTAICS. Photovoltaics (PV) have proven to be reliable in developing country applications in remote areas and when power requirements are small but important--for example, for communications, refrigeration, and for remote health facilities. At very small volumes (10-20 cubic meters) and in favorable solar conditions, photovoltaics are competitive with diesel for water pumping.

WIND MECHANICAL PUMPING. The main applications of wind mechanical pumping are for village water supply and livestock watering. Wind pumping competes favorably with diesel for water pumping when wind speeds are good, and where water volumes are low.

WIND ELECTRIC GENERATORS. Wind electric power generation for small loads is generally competitive with PV or diesel where wind speeds are good. Wind also is technically proven for larger grid-connected systems under appropriate conditions. Viability, however, is extremely sensitive to wind conditions at specific sites and alternative fuel costs.

BIOMASS FUELS--DIRECT COMBUSTION. Direct combustion of wood or other biomass for steam-raising can be cost-effective, though further down-scaling of currently available systems is necessary to serve the small size (25-200 kW) of many developing country applications. For electricity generation, the competitiveness of biomass combustion depends heavily on the relative cost of biomass fuel versus other alternatives, achieving minimum economic plant size, and fuel collection cost. Promising applications include use of wastes at sugar mills, wood product industries, and larger rice mills.

BIOMASS FUELS--GASIFIERS. Gasifiers are being used successfully for direct heat applications with a variety of fuels in a number of developing countries. Experience with gasifiers with internal combustion engines has been mostly unfavorable, though use of homogenous feedstocks and competent maintenance can result in cost-effective power production where diesel costs are high.

BIOMASS FUELS--BIOGAS. Success with biogas has been achieved with commercial-scale systems where biomass feedstock is available on-site. Household and community-scale systems have frequently been found to be uncompetitive with other fuels, hard to maintain, and difficult to manage.

ALCOHOL FROM BIOMASS. The viability of ethanol production, from sources such as sugar cane, as a substitute for gasoline depends upon the domestic cost of oil and the value that is placed on other factors such as foreign exchange savings and employment generation. Although ethanol production is not generally competitive at current oil prices, there are circumstances where it may be economically viable.

SOLAR WATER HEATING. Solar water heating is a commercial technology for urban residential and commercial purposes. It is often competitive with electricity for water heating. Industrial solar water heating is not generally attractive at current oil prices.

SOLAR DRYING. Solar drying by newly developed systems is feasible technically for agricultural drying, but it has not been widely used due to relatively higher cost compared with traditional systems. The energy and costs saved by solar dryers is normally relatively small, though the improvement in product quality is likely to be significant.

SMALL HYDROPOWER. Small-scale hydropower is a proven and common technology in the developing world for the production of off-grid electricity and the delivery of shaft power. Low capital costs (for example, from domestic manufacture and engineering), good water conditions, and high load factors are necessary for small hydropower to compete with other resources in electrical applications.

GEOTHERMAL. Geothermal reservoirs can be tapped to provide steam for electrical power production at a range of scales. Geothermal resources have been successfully tapped in many developing countries and represent a proven and normally attractive means of using domestic resources for power generation. The main constraints are availability of geothermal resources, and location versus electrical loads. Lower temperature reservoirs, which are more widely distributed, can provide direct heat for industrial processes.

SOLAR THERMAL ELECTRIC. Solar thermal electricity generation is in small-scale commercial use in California, under favorable conditions.

TABLE 3 CONVENTIONAL ENERGY TECHNOLOGY

DIESEL ENGINES. Internal combustion engines have been used extensively for both small and large scale applications requiring shaft power for a variety of loading conditions. Internal combustion engines offer many advantages over other prime moves, such as very low weight to power ratio, versatility, capability to operate under widely fluctuating load conditions, and the ability to be used for both stationary and vehicular applications.

Diesel engines are, in general, more rugged and less troublesome than spark-ignition engines, and for this reason have enjoyed wide acceptance for a variety of uses. Small and fractional horsepower internal combustion engines most often employ spark ignition, due to lower starting torque requirements than diesels. But for most commercial and industrial uses, diesel engines are the engine of choice for most users. They are most popular in sizes over 25 kW.

BOILER/DRYERS. Conventional (oil or coal using) boilers and dryers account for a sizable share of commercial energy consumption in developing countries. They are frequently used in intermediate to larger industrial and power generation (boilers only) applications. The cost-effectiveness of conventional boilers or dryers depends on the size of the system and the availability of low cost fuels. The most commonly found boilers are oil-fired, but their cost-effectiveness is limited because of high oil costs, foreign exchange requirements, and the need to transport fuel into rural areas. Agricultural dryers however, are commonly fueled by oil and biomass. In areas where there are locally available supplies of coal or oil, conventional dryers and boilers can be the most cost-effective means of raising steam and/or generating power.

DIESEL ELECTRIC AND GRID CONNECTED POWER GENERATION. Smaller-scale dispersed diesel fueled electric for rural areas, and large central station oil or coal burning power are the predominant conventional technologies for supply of power. Diesel generation suffers from high fuel cost but relatively low capital cost. Diesel generation is a very well established technology, however unreliable fuel supply, high fuel cost and difficulty in maintaining imported equipment make alternatives desirable. Grid connection for electricity supply is usually the most economic alternative where a connection already exists. However, in rural areas where extension transmission lines may be required to reach users, grid supply of electricity is extremely expensive. For this reason alternatives to grid supply are often the only feasible alternative for rural agro-processing industry.

Prospective Next Steps

The Office of Energy wishes to expand its support of mission rural development activities, in cooperation with the Regional Bureaus and other centrally funded programs of A.I.D., to provide support in areas discussed above. Potential areas of collaboration might include the following:

1. Surveys of agro-industrial development opportunities and energy requirements. Participation in multi-disciplinary teams to assess opportunities for rural industry, identifying infrastructure requirements and constraints, and energy equipment needs and manufacturing and marketing opportunities.

2. Assessment of institutional and training requirements to support private sector energy equipment manufacture, repair, and design of energy supply systems. Participation in the identification of institution building and training needs to support private sector rural industry; for example, help develop curricula and programs for local polytechnic institutes. Areas might include manufacture, repair, and design of production related energy-using equipment (such as dryers, sterilizers, grinding and milling equipment, pumps, refrigeration, etc.) and energy conversion technology (such as diesel engines, biomass combustion and wind systems, solar photovoltaic, and direct heat equipment). Other useful programs might include adaptation of similar imported equipment to local conditions.

3. Evaluation of important rural industrial sectors to determine potential energy conservation or alternative fuels sources or technologies. Provide technical assistance in the identification of energy conservation or fuel substitution opportunities which could assist resolve reliability and cost problems, or decrease foreign exchange requirements for major rural industry groups. These might include identification of process improvements, biomass for oil substitution opportunities, improved village or agricultural water pumping systems, etc.

4. Assessment of rural infrastructure and options to stimulate and support rural development. Evaluate energy supply infrastructure required to support rural development plans, particularly for decentralized industrial development. Assist in determining the most appropriate strategy to ensure that infrastructure is available in a timely, reliable and sustainable form. Assist private firms who wish to develop, produce or import energy supply or utilization equipment through technical, economic, and business advice.

5. Development of energy policy components of mission policy reform strategy. Assist in the evaluation of pricing, tariff and tax, or credit policies to present alternatives to stimulate

more efficient allocation of resources, including private sector agro-processing and energy marketing or manufacturing efforts.

Implementation Vehicles

The Office of Energy will be the focal point for implementing the prospective next steps detailed above. The implementation vehicles may be the Renewable Energy Applications and Training Project (REAT); the Bioenergy Systems and Technology Project (BST); and the Energy Policy Development and Conservation Project (EPDAC).

The Bioenergy Systems and Technology (BST) Project is intended to design, develop, and implement field projects using bioenergy systems. The project is presently funded to do work in three primary sectors: sugarcane bagasse, rice residue, and wood products utilization. This project provides support for prefeasibility studies, limited research in biomass utilization systems, field testing of new equipment, and promotion of private sector investment in energy systems utilizing the above biomass resources.

The Renewable Energy Applications and Training Project (REAT) has been responsible for the assessment of A.I.D.'s past experience with renewables and proposals for new initiatives to support rural and agricultural development. The project will be responsible for development of energy for rural development activities including helping to commercialize renewable technologies, coordinating renewable energy training, and providing general technology support and information support to missions for specific rural energy applications.

Household fuel activities are another area of emphasis. Current work includes investigation of markets for briquette fuel substitutes made from coal and/or biomass residues, especially in countries experiencing increasing wood scarcities. Household fuel strategy development work, and a review of charcoal stove programs in East Africa are also being pursued. Attention is also being given to understanding the fuel saving and the health and environmental impacts of improved cooking devices.

Energy and irrigation activities are designed to promote the economic utilization of water for irrigation in A.I.D. assisted countries. The activity supports improvements in the performance of existing small water pumping systems, promotion of integrated small-systems for water supply for irrigation, and dissemination of information.

The Energy Policy Development and Conservation Project (EPDAC) is designed to provide assistance in a variety of areas including identification and implementation of economic and

reliable approaches to supplying rural electric power, improving the management of the environmental impacts of energy development, supporting energy price reform intervention and strategy, and supporting energy conservation activities.

Another relevant project under the Office of Energy relevant to energy for rural development activities is the Energy Training Project.