Rural Energy: A Practical Primer for Productive Applications

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This is part of a series of straightforward and practical (rather than an academic) papers by leading experts and presented in a specially designed format as brief and basic teaching tools with resources for more in-depth expertise. They address topics relevant to the design, monitoring, and assessment of projects and interventions for the promotion of agricultural enterprises and markets in developing countries.

Keywords: *Energy, rural electrification, renewable energy, energy technologies, decentralized technology, energy systems, infrastructure, hydroelectric, biomass, biopower, wind power, solar power, hybrid power systems, photovoltaic, geothermal, microhydro.*

Abstract: *Lack of access to reliable and affordable electricity services in rural areas significantly diminishes the opportunities for the development of many economically productive activities, including agro-enterprises and fishing. Reliable and affordable energy is a vital input to many agricultural and post-harvest processes. Adding energy to agricultural production and processing, often the largest employer in rural areas, is an important way to grow beyond subsistence farming and the supply of raw materials toward the potential of added value. Fortunately, there are decentralized and commercially proven energy alternatives including those that harness renewable energy. Many of these are now technically and financially viable, even in remote rural areas. This learning tool provides an overview of these technologies and their appropriate applications in the field, and includes best practice examples used on a significant scale in agriculture, aquaculture, fishing, and related enterprises (e.g., food processing) in many developing countries. It explores necessary considerations in the choice of energy and how such projects could be formulated and executed.*

> …an important opportunity becomes evident: rural areas of developing countries could "leapfrog" to more sustainable energy systems, and, in fact, to more stable food security conditions. By utilizing the potential offered by renewable energy sources…these rural areas can become examples to other sectors of society, both in developing and industrialized countries.
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> Gustavo Best (March 1996). *Future energy requirements for Africa's agriculture: Findings and recommendations of an FAO study.* UN Food and Agricultural Agency (FAO)

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1. Introduction

Lack of access to reliable and affordable electricity services in rural areas significantly diminishes the opportunities for the development of many economically productive activities, including agro-enterprises and fishing. Reliable and affordable energy is a vital input to many agricultural and post-harvest processes. Adding energy to agricultural production and processing, often the largest employer in rural areas, is an important way to grow beyond subsistence farming and the supply of raw materials toward the potential of added value. Nevertheless, in many rural areas the conventional method for supplying electricity, by linking to the national or regional electricity

grid, is sometimes economically or logistically unfeasible. Fortunately, there are decentralized commercially proven alternatives to conventional grid extension that are technically and financially viable, even in remote rural areas. Renewable energy technologies are an important subset of the decentralized alternatives that are now commercially available and increasingly used in the agriculture and food sectors.

This paper explores opportunities to incorporate practical energy technologies for productive uses in the developing world. These include the production and processing of agricultural products, fishing, aquaculture, and livestock. These are the principal activities of rural societies and account for 20 - 60% of the gross domestic product (GDP) of many developing countries. Although affordable and reliable energy offers various benefits for residents in these areas, the focus of this document is more on direct applications of renewable energy technologies to help meet specific business and productive applications in rural communities rather than consumptive or home uses of energy.

The Need for Access to Modern Energy Services

Most of the rural population of the developing world lives without access to formal electrification. Roughly a third of the six billion people worldwide live in un-electrified communities, and perhaps one billion more have poor quality electricity services, with limited hours of availability, blackouts, under-voltage, and poor frequency stability. Electricity is one of the prerequisites for significant sustainable economic growth. Reliable and reasonably priced energy is an essential ingredient for many aspects of improved or value-added agricultural and post-harvest processes. This also applies to livestock and fish processing as well as to aquaculture. For simplicity we use the term *agro-enterprise* to encompass all of these productive rural activities. Modern energy supply also enables more intensive agriculture by providing irrigation (pumps) and immediate post-harvest treatment (cooling) and storage. Applications include the use of electricity for ice making, refrigeration (crops, produce, fish, etc.), food processing, shops, and other income generating activities.

New Sources of Income and Other Values of Rural Energy

In addition to the central role of energy in productive processes, it is also essential for assuring sufficient volumes of potable water, and for other community applications including modern schools, health facilities, telecommunications, and government offices.

An emerging and still commercially experimental approach to the large-scale application of decentralized energy systems and services is that of the rural energy services company (RESCO). RESCOs typically own the energy production and supply equipment, and charge for energy services on a fee-for-service basis. This frees farmers, entrepreneurs, and businesses to focus on income generation and not on energy supply, and relieves them of both the financial and technical risks associated with the energy production equipment.

Providing reliable and affordable energy to rural areas can require a costly investment in both infrastructure, maintenance, and fee collection. Improved technologies in recent years have shifted the landscape from traditional large-scale centralized power production and associated large electric power networks or “grids” to more reticulated and decentralized systems. In some cases renewable systems and hybrid systems (renewable/fossil fuel) prove to be more reliable, more environmentally friendly, and more cost-effective than fossil fuel systems alone. In many cases, renewable energy technologies and hybrid systems can provide energy services that can easily support productive enterprises, particularly in the food and fiber sector. The discussion here focuses on the following:

- Available decentralized energy technologies and their characteristics
- Productive uses for which these technologies are well suited
- Methods for selecting an appropriate energy technology or technology mix
- Examples of such applications from around the world

2. Key Issues in the Rural Sector

There are alternatives to the costly extension of the public electric power grid: the installation of local micro-grids with one or more dedicated power generation units or the use of individual or stand-alone systems that provide electricity for specific dedicated applications. If the grid is available and sufficiently reliable, it is usually the first choice for power supply. In some cases, the grid power may not be sufficiently available, reliable, or of the necessary quality for some end use applications. Poor quality power can damage or destroy motors and sensitive electronic equipment. Power outages result in decreased productivity, and often motivate end users to purchase costly backup power supplies. Hence the availability and quality of required electricity services is an important determinant in the source of electricity.

Renewable energy technologies including hydroelectric power plants, biomass-based cogeneration, and wind electric power generation) are widely used for large-scale electricity and can be readily adapted for smaller scale rural applications. Hybrid power systems that combine fossil fuel-fired generators (e.g., diesel and propane generators) with wind and solar electric power units are increasingly used to provide reliable high-quality off-grid power. From both an economic and an environmental point of view, renewable energy systems often can provide the energy needed for decentralized economically productive activities such as agriculture and fishing.

2.1 Costs and Economic Issues with Renewable Energy Installations

Renewable energy installations typically have larger initial costs and lower operating costs compared with fossil fuel systems. When investment decisions are made on a first cost basis, diesel and propane (or LPG – liquefied propane gas) driven electrical generators will be selected even if over the long run they are less reliable and more expensive than a renewable energy option designed to provide the same energy service with less environmental impact. Basing investment decisions on first costs often undervalues the lower-cost long-term operation of renewables relative to fossil fuel plants. It also ignores the significant uncertainty in long-term fuel prices and availability. The costs of most renewable energy installations are "front end loaded", so the long term costs and net present values of these systems are much more predictable than installations in which unpredictable fuel costs dominate the long-term system costs. For many developing countries, power generation equipment for rural applications are often provided through grant aid and concessional loans. However, such grant-based and concessional financing rarely provides support for sustainable operation and maintenance, which requires local training and capacity building, sinking funds for periodic and episodic replacement of capital equipment, and funds for operation and maintenance. When such assistance provides renewable energy equipment, the primary recipients of the financing are often the donor country equipment suppliers, and investments in infrastructure to make such equipment and services sustainable are usually the responsibility of the host country. Most such donor-driven initiatives have resulted in the rapid or gradual failure of the power systems; there are only a few examples of truly sustainable implementation.

Many conventional energy systems enjoy both overt and hidden subsidies that provide them with a financial edge. The costs of the environmental impacts of fossil-based energy systems are almost never reflected in the price of the fuels and are not recovered from the fuel users. As such, society bears these costs. Fossil fuels also enjoy direct subsidies ranging from reduced or eliminated transport tariffs to resource depletion allowances. In many countries where fossil fuels are imported, they are exempt from import duties. Alternately, renewable energy systems seldom enjoy direct or indirect subsidies despite their environmental benefits and foreign exchange savings. In addition, many imported renewable energy products are often subjected to substantial import duties and taxes. The net result is that renewables face higher financial costs when compared to conventional energy systems. In effect, the benefits of renewables are taxed while the damages of conventional systems are subsidized.

2.2 Overview of Technologies and Applications

Examples are presented here to illustrate how renewable energy technologies can be and are being used to enhance the productivity, quality, and value of food production enterprises. There is a considerable variety of technologies, applications, and scale of energy production and distinct lessons from each; these examples provide a basic knowledge.

Agriculture not only uses energy, it is also sometimes a *source of energy* for thermal energy and electricity production. Bioenergy technologies are used widely and on a significant scale in agriculture and related enterprises (e.g., sugar refining) in many countries, including most of the OECD countries. Agricultural residues that can be used as high-quality fuels for production of heat, electricity, and both simultaneously (cogeneration) include coconut shells, coffee husks, bagasse, rice hulls, palm oil nut shells, and ground nut shells. Poultry waste is also being used increasingly as a fuel source in advanced cogeneration plants, for production of both heat and electricity.

Table 1 presents some of the uses of solar heat and biomass combustion systems in agriculture. There is an enormous untapped potential for the use of biomass residues from sustainable agriculture in much of the developing world.

Table 1. Small-scale Agricultural Applications of Solar and Biomass Thermal Systems

Agricultural Application	System Type	Temperature, Daily Heat Delivery Range
Cleaning, sanitation	Solar water heating (flat plate units)	40°C - 70°C
Production of high-value fruits, spices, exotic house plants, etc.	Greenhouses	Ca. 20°C - 30°C
Crop Drying (coffee, tea, fruit)	Hot air systems -- solar "tents" and dryers, sometimes with electric fans for air movement	40°C – 70°C
Poultry Processing	Solar hot water (flat plate or concentrating systems for high-temp water)	40°C - 100°C
Poultry Processing	Combustion of poultry litter as a source of both process heat and power generation to operate processing facilities	high temperature
Coffee drying and processing	Coffee husks used as fuel for biomass furnaces to provide heat for drying and processing	100 - 700 kW thermal
Rice paddy drying	PADISCOR (Filipino) rice hull-fired dryer. 230 kg/hour rice hulls dries 8,000 kg/hour of paddy	
Water pumping (irrigation, livestock watering, potable water)	Biogas fueled power generators	

Table 2 presents some of the renewable energy and renewable/fossil fuel hybrid power systems options that are available for decentralized application in the food/agriculture sector. These include photovoltaic (PV) conversion of sunlight to electricity, wind electric turbines, wind / PV / fossil fuel hybrid power generation units, bio-energy conversion, and hydroelectric power generation. Diesel generation units are also an important and widely used decentralized power option. All of these technical options can provide reliable and high-quality energy supply provided there is a competent local infrastructure support that can assure operation, maintenance, and repair of the equipment.

Table 3 illustrates specific applications of PV and wind electric technologies for agro-enterprises. All of the applications presented are in actual use and using commercially available equipment. However, applications that are common in some regions may be little used or virtually unknown in other regions, even if the circumstances in the latter case are favorable for the use of these applications. A few of the applications are novel, and not well known. An example from southern India is the use of PV-powered lanterns in a simple, highly effective, pesticide-free mechanism to destroy voracious insects and thus reduce post-harvest losses of certain cereal crops from 50% to less than 10%.

Solar energy conversion includes processes to produce heat, electricity, and biomass that can be converted to fuels, heat, mechanical or shaft energy, and electricity. Figure 1 indicates solar energy conversion pathways for which there are practical commercial technologies available. Solar heat is used for applications such as crop drying, ice making and cold storage (through absorption or heat-driven refrigeration), and poultry processing (hot water).

Wind energy conversion has been used for thousands of years to produce mechanical energy for grinding, milling, and water pumping. Modern wind electric turbines produce electricity on a scale ranging from a few hundred watts to over 1 megawatt by a single machine. Wind electric water pumping units have been developed as a specialized application of wind energy conversion, for irrigation and potable water supply.

Biomass energy conversion involves the conversion of agricultural residues from the production of sugar, coffee, rice, cotton, cacao, palm oil, and other crops. Combustion provides heat and electricity for agro-industry, typically in the range of hundreds of kilowatts to tens of megawatts. Biomass energy conversion processes include combustion, gasification, fermentation (e.g., to produce alcohol fuels), and anaerobic digestion (to produce methane-rich biomass that can be used as a fuel for generating heat and electricity). The terms *biopower* and *bioenergy* are both used for biomass-based power generation and cogeneration (heat and electricity production) systems.

Small-scale geothermal energy involves the use of geothermal hot water in the range of a few hundred kilowatts to ca. ten megawatts. Higher temperature water and steam (above 100° C) can be used to drive turbines that in turn generate electricity. Lower temperature water sources are used in direct thermal applications that include greenhouses, crop drying, fish farming, and dehydration of fruits. These thermal energy sources can also be used for air conditioning, refrigeration, and ice making by using heat-driven refrigeration units.

Microhydro energy conversion produces shaft energy and electricity in the range of kilowatts to hundreds of kilowatts. Larger installations (**mini-hydropower and small hydro**) can provide electrical power up to tens of megawatts.

Following are some important agricultural applications of heat, mechanical / shaft energy, and electricity:

- *Electric fencing* for range management, to keep animals inside grazing areas and out of farms and other sensitive areas.
- *Electrically-driven irrigation*, including water-conserving drip irrigation methods. Irrigation consumes a large proportion of the energy in the agricultural sector in many developing countries. In India, for example, 70% of the rural electricity consumption in 1985-86 was used for water pumping[2]. Irrigation most commonly is accomplished either by electric motor or diesel driven pumps, but wind power, photovoltaics or natural gas and even manual treadles can also be used to run pumps at significant cost savings. Secure energy supply is

[2] fertilizer production, typically the big consumer of agricultural sector energy, often does not occur in rural areas.

an important issue as failure to provide energy for pumping can be devastating in areas relying on irrigation for food supply.

- *Livestock watering* is one of the major applications of photovoltaics in agriculture. PV-supplied electric heating is also used to prevent ice buildup in livestock watering units in cold climates in winter.
- *Crop drying* using greenhouses, solar thermal energy production, geothermal energy, and biomass combustion [example: The PADISCOR rice hull-fired dryer in the Philippines, biomass-fired coffee drying in Central America, fruit dehydration in Africa]
- *Grain grinding and milling* using power generated from biomass and microhydro power
- *Aeration and water pumping* for fish and shrimp farming
- *Refrigeration* for fish, fruits, meat, and other food products. Controlled temperature storage is a critical factor for most perishable agricultural products. A consistent cold chain is a necessary asset to maintain the quality of many high-value agricultural products. In addition to storage at central hubs and transportation centers more localized storage is often necessary since some products can experience a shelf life diminished by a factor of 8 times the length of delay between harvesting and cooling.
- *Ice-making* for fish and meat preservation
- *Post-harvest processing* can add value and help improve incomes for both farmers and non-farm rural enterprises. Indeed as supply chains develop, value-added processes help differentiate product suppliers and may even become requirements for access to more sophisticated, high-value markets. Post harvest processing requiring electricity can take many forms: milling, sorting and grading conveyors, oil expelling, dehydrating, canning, bottling, and packaging.

Case examples of these and other applications of renewable energy for agriculture are presented in the Annex, along with links to sources of more detailed information.

Table 2. Renewable and Fossil Energy Technologies Relevant to Off-grid and Mini-grid Electricity Applications in Agriculture and Food Production

Technology	Experience Worldwide	Commercial Status and Applications
Photovoltaics (PV) (from tens of watts to several kilowatts)	Extensive 1,000 MWp installed globally. Global production is 250 MWp/year in 2001	Fully commercial, very wide range of applications including off-grid community uses. Agricultural uses: Water pumping / small-scale irrigation, lighting, low-power agricultural processing.
Small wind electric turbines (300 watts to 20+ kWe)	Extensive	Commercial, and evolving rapidly; well-suited for water pumping for small-scale irrigation, and battery charging applications (for running lights and communications), and for use in hybrid power systems
PV/diesel hybrids (20 - 500 kWh/day)	Extensive, especially for telecommunications	Fully commercial and the preferred option for remote telecommunications, commercially evolving for village power and rural agricultural applications.
Wind/diesel hybrids (20 - 2,000+ kWh/day)	Significant, not yet extensive	Commercial, often competitive, and evolving; especially relevant to island communities
Small modular bio-power (10 kWe to 100+ kWe)	Commercial prototype installations underway, commercial availability projected for years 2003/4.	Under development, new commercial products becoming available in 2001/2002. First 12 kWe commercial prototype to be installed in a RESCO in the Philippines. Good potential for providing electricity and heat to farms and farm communities if sufficient appropriate biomass residues are available.
Diesel generators (10 kWe to hundreds kWe)	Extensive, worldwide.	Fully commercial at sizes ranging from several kilowatts to tens of megawatts. With high-quality maintenance, diesel gensets can operate reliably for 20,000 hours or more. Rural applications are usually for medium to large-scale irrigation, and for village minigrids, especially for lighting and entertainment / information (TV, radio).
Cycle-charge diesel systems (batter/inverter added to diesel genset)	Used in remote power applications, and for village power in some countries	Fully commercial. Especially applicable when low-power daytime electricity is required for isolated 24-hour powered community minigrids.
Bioenergy Systems (0.5 MWe to 20+ MWe)	Extensive, in wood and agro industries worldwide, especially southeast Asia, and in most OECD countries.	Commercial site-engineered systems, relevant only to the extent that sustainable sources of biomass residue are available locally.
Microhydro (0.1 kWe to 1 MWe)	Extensive, good experience in many developing countries (e.g., China, India, Indonesia, Philippines)	Fully commercial; wide variations in design, performance, reliability, and price. Huge potential for economic power supply in Asian countries with intact watersheds.

Table 3. Small-scale Agricultural Applications for PV and Wind-Electric Systems

Agricultural Application	RE System Type	Typical Peak Power Range (peak kW)
Irrigation (especially drip irrigation and micro-spray techniques, sometimes incorporating fertilizer delivery)	PV, wind electric submersible and floating pumps, microhydro power generation	1 – 3
Chicken egg incubation	PV lights (solar thermal heating)	
Crop spraying	All renewable energy power generation	
Livestock watering	PV, wind electric submersible and floating pumps, electric heating to prevent water freezing	0.5 – 1
Electric fencing (grazing management), gate opening	High-voltage current-limited supply from PV, wind electric, with batteries, inverters, transformers	20 – 100 watts (50 watts for 15 km of fencing
Farm lighting (including security and safety of scattered buildings)	PV/battery system lighting (typically low-voltage DC, fluorescent lamps)	50 – 500 watts
Forced ventilation in greenhouses, crop dryers (coffee, tea, sesame seeds)	PV-driven fans	0.1 – 1
Coffee drying and processing	Coffee husks used as fuel for biomass furnaces to provide heat for drying and processing; small-scale geothermal energy sources	
Lighting (poultry, livestock, fish, and horticulture processing)	Fluorescent lighting	0.2 – 3
Water pumping -- fish farming	PV, wind electric pump sets	0.5 – 3
Aeration -- aquaculture (shrimp and fish farms)	PV, wind electric air pumps	0.2 – 1
Light for night fishing [Indonesia, Philippines]	PV rechargeable fluorescent lanterns	10 – 20 watts per lantern
Pest control (moths)	PV lanterns with kerosene insect traps, electrical traps [India]	10 – 20 watts per lantern
Refrigeration for veterinary applications	PV fridges	50 – 100 watts
Refrigeration (fruit and other crops, meats, fish, poultry, dairy products)	Wind, PV hybrids with fossil fuel generation: refrigeration units (compressor-driven)	0.5 - 10+
Decentralized refrigerated milk storage units	Wind-electric with double wall ice storage, or with fossil backup (experimental)	
Ice making (flake ice for fishing)	Wind-electric ice makers	2 – 10
Telecommunication (e.g., to permit local fishermen to determine market prices and opportunities in major urban markets)	PV-powered cell phones, PV-powered satellite phone kiosks (e.g., Bangladesh -- Grameen Shakti operations)	0.2 – 0.3
Radio and television information	PV and PV/wind hybrid powered radios and TV sets to provide weather information to farmers and herdsmen, and to food shop owners	
Grinding of corn, wheat, and millet, and milling of grain-hulling paddy	PV/wind/hybrid powered electric grinders and millers	0.5 kWe - several kWe
Post-harvest loss reduction of grains	PV-powered ultrasound generator to jeep rodents away from grain storage	< 100 watts

3. Selecting Which Energy Technology Mix to Use and Moving Forward

In many cases even modest energy inputs or resources can substantially improve the productivity of the sector. Many rural development specialists may not know that small to mid-scale rural energy has become simpler, more affordable and more feasible in recent years due to a growing range of modular options with improved reliability and scalability. The World Bank and the United Nations Development Programme (UNDP) are introducing *rural infrastructure agents* in several new rural renewable energy projects to assist local farmers, fishermen, and communities in identifying practical ways to obtain reliable and affordable energy services from renewable sources. To facilitate bringing a productive energy component to a rural area there are some steps to consider:

Step 1. Project identification and pre-investment

a. ***Briefly characterize and quantify the added value gains from enhancing energy input for select productive uses.*** For example, if there is local production of fresh fruit, then how much greater is the market value of dehydrated fruit, including calculations for reduced shipping costs and reduced perishability i.e. dried mango is an extremely high-value product and in great demand. What extra value does processed poultry have over fresh poultry in the marketplace?

b. ***Survey the specific use of energy in existing productive activities to understand energy supply and consumption patterns.*** Each step in the chain of food production, processing, storage, and packaging uses mechanical, thermal, and/or electrical energy. The peak power requirements (rate of energy delivery), the average demand for energy, and energy quality are all essential specifications. For heat, this means specifying the form of thermal energy (hot water, steam, hot air, etc.) and the temperature. For electricity, it means the peak and average power demand, the hours of availability, and the quality of the power in terms of frequency and voltage stability, lack of electrical “noise”, etc. How sensitive is the process to disruptions in energy supply?

   Are there opportunities and is there interest from the business to produce its own energy. For example, by converting crop residues, energy can be produced through biomass fermentation, combustion, pyrolysis, or gasification

c. ***Survey of local energy resources.*** Questions to pose are: Are renewable sources available such as biomass residues, good wind resources, streams and rivers that can be harnessed to generate electricity in environmentally and socially acceptable ways, and strong sunlight? Is there a functioning and reliable infrastructure for fuels such as propane, natural gas, or diesel fuel? Is the area electrified and if so will this be a primary or a backup system? How reliable are the local electricity supply and the delivery of modern fuels?

d. ***Select energy generation options by matching demand characteristics and patterns with an appropriate technology.*** Assess the types of energy sources and technologies that best cover the identified needs. Then match the end use with the energy sources and energy equipment available.

e. ***Assess whether there are potential health or environmental issues and/or benefits.*** Rather than burning wood and other biomass fuels, switching to cleaner fuels has been shown to save $100 to $200 per Disability Adjusted Life Year (DALY) per person in developing countries. In rural India, shifting from fuel wood to cleaner sources of energy (like kerosene and LPG) halves the mortality rate for children under five, this household data is likely to have correlations for adults in the workplace. Questions to ask: Are the environmental and noise pollution, costs, and spilled fuel impacts of the use of diesel generators acceptable?

f. ***Determine whether there is adequate support of infrastructure for the selected technology.*** Sustainable use of any energy equipment requires that there be a competent and reliable local infrastructure to maintain, service, and repair the energy systems under consideration. If such support is not available, can it be established as part of the investment in specific energy supply systems?

g. ***Perform a simple economic analysis of the most promising alternative(s).*** While the initial costs of capital and expertise of renewable energy systems may sometimes be higher than those for fossil fuel based systems, the subsequent savings in fuel costs, replacement costs, and maintenance over the life of the system can be substantial. The availability of financing and the associated loan terms and conditions will influence whether the end user chooses low capital cost options or low life-cycle cost options. The typically high interest rates of local banks in most developing countries, and the lack of experience of most banks in lending for renewable energy systems will actively discourage the use of such systems.

Step 2. Project preparation/feasibility

a. ***Confirm the real demand for energy and the client's willingness/ability to pay.*** Even if a project is fully subsidized for initial costs, it will only be sustainable if the user earns enough marginal value to pay the replacement costs in addition to the operating and maintenance costs – and is willing to do so. In countries where electricity has been heavily subsidized, end users in rural areas may refuse to pay even low tariffs designed just to cover operating and maintenance costs.

b. ***Arrange the necessary economic, financial, and site engineering analyses.*** These should include appropriate risk analyses, detailed costing of the selected energy options, and a defined financing plan, all prepared with the close participation of the clients.

c. ***Ensure that clients are adequately trained in the operation, management, maintenance and repair of the equipment and that there are viable back-up measures in case of energy supply failure.*** This essential establishment of local capacity is rarely achieved for rural energy supply, whether for small diesel generators or for renewable energy systems.

d. ***Prepare, in close collaboration with client, a system of monitoring and evaluation that is easy to manage and measure.*** Besides measuring the success of the project and its impact, it is important that the clients themselves can see the relative costs and benefits of their energy technology. This intimate understanding can also improve payback rates or adherence to a fee for service plan.

Step 3. Project appraisal and preparation

a. ***Develop procurement or bid.***
b. ***Confirm financing and security requirements.***
c. ***Prepare agreements for payback and/or fuel supply.***
d. ***Secure necessary licensing, permits, and clearances***
e. ***Obtain energy and product off-take agreements (e.g., electricity purchases by local electric utilities, cooperatives, and industries).***

4. Information and resources

4.1 Magazines and Journals

- *Renewable Energy World (UK)*, one of the most comprehensive publications of its kind, and available free from the publisher James & James (UK). www.jxj.com/rew. A detailed supplier listing is at www.jxj.com/suppands/renenerg/
- *Home Power Magazine (US)*

4.2 Books

- *"Handbook of Energy for World Agriculture"*, B. A. Stout, Agricultural Engineering Department, Texas A&M University, College Station, Texas, USA, 1990.
- *"Energy Use and Management in Agriculture"*, B. A. Stout, Agricultural Engineering Department, Texas A&M University, College Station, Texas, USA, 1984.
- *"Handbook of Agricultural Energy Potential of Developing Countries",* 4 volumes, James A. Duke, CRS Press Inc., 1987.
- *"Alternative Energy in Agriculture, volume I and II"*, D. Yogi Goswami, CRS Press Inc, USA, 1986.
- *"Rural Energy and Development – Improving Energy Supplies for Two Billion People*", The World Bank, 1996.
- *"Fueling Development – Energy Technologies for Developing Countries"*, U.S. Congress, Office of Technology Assessment, OTA-E-516, 1992.

4.3 CD-ROM documentation

4.4 Web sites

- Center for Renewable Energy and Sustainable Technology (CREST)
  www.solstice.crest.org

- National Rural Electric Cooperative Association (NRECA)
  www.nreca.org

- National Renewable Energy Laboratory (NREL)
  www.nrel.gov and a new renewable energy website hosted by NREL. NREL has launched the Renewable Energy Analysis Studies Network (REASN), at http://www.nrel.gov/reasn.

- Sandia National Laboratories
  www.sandia.gov

- Winrock International
  www.winrock.org

- FAO, the Food and Agriculture Organization of the United Nations have some information about energy in agriculture on their web page:
  http://www.fao.org/WAICENT/FAOINFO/SUSTDEV/EGdirect/EGhomepg.htm

- The World Bank's Energy department has information about their work and energy in developing countries on: http://www.worldbank.org/html/fpd/energy

- World Bank/UNDP Energy Sector Management Assistance Programme (ESMAP)
  http://www.esmap.org