

Electricity on Demand:

*Reaching Two Billion Cheaply
With Renewable Energy*

 Winrock International

July 1998

Contents

Overview.....	3
People Without Power.....	4
Why Traditional Power Supplies Don't Reach Rural Areas	5
How Much Power Is Needed?.....	6
Current Options Are Limited.....	6
Types of Renewable Energy.....	8
The Cost of Renewable Energy.....	12
Financing & Credit.....	14
The Advantages of Renewable Energy	18
Improving Quality of Life and Standard of Living	18
Natural Resource Management	20
A Size for Every Need	21
Power Where It's Needed	21
Harvesting Energy	23
Winrock's Renewable Energy Strategy.....	24
The International REPSO Network	26
Renewable Energy Solutions to Real Problems.....	31
About Winrock International.....	35
Power – Definitions, Ratings and Consumption.....	36
References	39

OVERVIEW

Nearly 2 billion of the world's people live today without electricity. Most are the rural poor who reside in areas not yet reached by centralized electric power grids. The developing countries these people call home do not have the financial resources to expand utility lines to reach these areas, and there are few incentives for doing so. Populations are isolated and their ability to pay for service is limited. Even when power lines do reach rural areas, supply can be erratic. When there are power shortages, rural dwellers are the first to suffer.

Electricity can improve the quality of life for the rural poor and is often used to pump water to homes, farms and small businesses. It allows for increased production and therefore raises the standard of living. The time saved through use of electricity – for instance, pumping irrigation water instead of carrying it by hand – can be used for additional income-generating activities or, in some cases, can allow children to attend school.

For just pennies a day, renewable electric power can be brought to rural people by tapping the locally available energy from the sun, wind, water, geothermal, and biological sources. Renewable energy systems can bring electricity to rural families for approximately \$50 to \$100 per person of initial investment. Even in the poorest areas, the desire for electricity is so strong that people will pay a large percentage of their income for energy. Access to credit or financing would allow people to pay for system acquisition and installation. Investments in training and institutional strengthening lead to long term development and maintenance of renewable systems and services.

Winrock International acts as a catalyst. It assists governments, private enterprises, nongovernmental organizations (NGOs), and international institutions in developing replicable projects that bring electricity to the poor. Winrock does not sell technology, but rather links demand for electricity with suppliers of renewable energy systems. It focuses on developing policy, assessing renewable resources, and removing barriers that impede system development and use of these sustainable, non-polluting resources.

U.S. dollars are used for all costs mentioned in this report.

People Without Power

Currently, nearly two billion people, or more than a third of the world's population, live without electricity in areas too remote or poor to support traditional electrical systems. Nearly all live in rural areas where the World Bank estimates 80 percent of the world's poor reside. Only four of 10 rural people have electricity, and in sub-Saharan Africa and South Asia where the world's poorest people live, it is not uncommon for only one person in 20 to have access to electricity.

Table 1 lists the countries where Winrock International has initiated energy programs. It shows the wide disparity in electrification status even among countries with similar levels of per capita income.

Table 1. Disparity in Electrification

Countries	Population (millions)	GNP per Capita in US\$	Commercial energy use per year in kg of oil equivalent	Electrified Population %	Urban Population %	% Poverty (living on < \$1 a day)
Nepal	22	200	28	14	14	53
India	929	340	248	43	27	52
China	1200	620	664	75	30	29
Indonesia	193	980	366	41	34	14
Philippines	69	1,050	316	55	53	27
Guatemala	11	1,340	210	N/A	42	53
Dominican Republic	8	1,460	337	N/A	65	20
Mexico	92	3,320	1561	N/A	75	15
Brazil	159	3,640	718	91	78	29
United States	263	26,980	7819	100	76	N/A

Sources: World Development Report 1997 and Energy and Industry Department of the World Bank.

Why Traditional Power Supplies Don't Reach Rural Areas

Developing countries are producing large amounts of electricity, but it often does not reach rural populations for reasons including the following:

Population Growth – Aggressive rural electrification programs begun in the 1970s have reduced the absolute numbers of those without electricity in China, Latin America, East Asia and the Pacific. But in North Africa and the Middle East, sub-Saharan Africa, and South Asia, electrification has fallen behind population growth. Although more than 1.2 billion people worldwide have gained access to grid-connected electricity in the past 20 years, global population has increased by more than 1.5 billion during the same period (Kammen 1996). The net result is that despite these efforts more people are without electricity today than when these projects began.

Increased Demand from Existing Customers – Although electrical generation in many developing countries has kept pace with or surpassed the rate of population growth, per capita consumption of electricity has increased in the already electrified urban areas so that the additional power is consumed largely by existing customers. A case in point is India. India's population increased at an average rate of 2.1 percent in the 1980s. Although electrical generation increased at an average rate of about 9.1 percent (Meyers, et al 1993), more people were without electricity at the end of the 1980s than at the beginning. Rural people may move to cities to access modern amenities and services, further contributing to the urban draw on the electrical grid.

Profitability of Extending the Grid – Typically, utilities reach new customers by extending the electrical grid. In developing nations, electricity generated by large centralized plants often does not reach rural populations because there are geographic or economic barriers to accessing conventional grid electrification (Kammen 1996). The cost of extending existing grids typically ranges from \$3,000 to \$10,000 per km (Foley 1995), so extremely remote or inaccessible areas can be quite costly to reach. If the expense of grid expansion is to be offset by payments for energy, extending the central power grid to rural areas is not commercially attractive for other reasons: the average household demand is low and the rural poor have limited financial resources for payment. So, for most rural consumers, prospects of electrification from the grid are poor (Acker and Kammen 1996). Large subsidies are needed if traditional methods are to be used to bring power to remote areas.

Low Priority – Even when they are connected, rural areas are the first to be turned off during power shortages. So, although the large investment in grid extension may be made, the resulting power might prove unreliable.

Internal Conflict – There are many internal conflicts that keep rural communities from connecting to national power grids even when the grid is within an affordable distance and local people can pay for service. These usually stem from disagreements over cost sharing.

New strategies using decentralized energy systems are needed if the vast majority of people are to have access to electricity within the next quarter century.

How Much Power Is Needed?

The amount of electric power needed by rural people to meet their modest requirements for lighting and communication is much smaller than the demand of urban populations and industries. In many countries, one year's growth of power supplied by the national grid would be sufficient to electrify the entire rural population through small, decentralized systems (around 50 W (watts) per household).

With from 15 to 100 W of electricity, a family can power lights, a small television or radio, and perhaps another household appliance. A kW provides enough electricity to light 10 to 20 rural households or power a solar irrigation pump. A MW would power lights for a town of around 3,000 families and some daytime industries such as agricultural mills, sawmills, arc welders, or baking ovens.

Current Options Are Limited

Without a connection to a central power grid to receive electricity, people must pursue other options. Diesel-powered generators (gen-sets) are widely used, but are prone to mechanical problems, require skilled operators to run trouble-free, and need a trained mechanic when problems arise. Additionally, small gen-sets are expensive. While large industrial-scale generators tend to be cost effective

because of economies of scale, smaller village systems are disproportionately expensive both to purchase and operate. Private, diesel-based mini-grids in developing countries often charge more than \$1 per kWh (Foley 1995), over twice the cost of energy from solar home systems.

In remote mountainous areas, diesel fuel for gen-sets must be carried in on the backs of people or animals. This makes the fuel very expensive and the supply highly unreliable. People in these areas thus prefer to rely on locally available sources of energy.

Without a gen-set, villagers may use candles and kerosene for lighting, and dry cell batteries for transistor radios and flashlights. These tend to be much more expensive than electricity generated from renewable sources.

Winrock's strategy of introducing small-scale renewable energy sources to the rural poor of developing nations is a way to provide power quickly and inexpensively, with control of power delivery maintained at the local level.

Types of Renewable Energy

SUN – Sunshine, or direct radiation, is the portion of light that comes straight from the sun. This solar energy varies with location, time of day and cloud cover. Many developing countries are located near the equator where the sun's radiation is most intense. They have high levels of sunshine year-round, providing a free and abundant energy supply. In some cases, sunshine may be a country's only domestic energy resource.

The amount of solar energy falling on the earth every year is equivalent to 160 times the energy stored in global reserves of fossil fuels. It is more than 15,000 times greater than the annual use of fossil and nuclear fuels and hydropower combined (Boyle, p. 28).

Sunlight can be harnessed by photovoltaic (PV) or solar cells. These cells are usually made of silicon that has been treated to form an electrical field that is positive on one side and negative on the other. Sunlight striking a solar cell knocks free electrons from the cell's silicon atoms. When electrical conductors are attached to both the positive and negative sides, they form an electric circuit that captures the loosened electrons in the form of electricity.

The larger the surface area of a panel, the more electricity it will produce. For that reason, solar panels often are attached together to form larger units. Two or more solar panels mounted on a frame form a PV module. Two or more PV modules attached together form a PV array.

The sun's energy can be stored in batteries during daylight hours for use 24 hours a day. PV equipment usually is connected to a battery or series of batteries that can store energy for later use.

Solar energy can be concentrated by reflecting light and heat with parabolic mirrors. This technology provides heat at up to several thousand degrees Celsius, and may be used for heating purposes or to generate electricity.

PV systems are especially well suited for use in rural areas where large populations remain isolated from existing power grids. A typical household PV system provides enough energy to light several rooms and operate one or two appliances, such as a radio, television, electric fan, blender, or sewing machine. Today, these systems are successfully operating at thousands of sites worldwide.

WATER – Water has been used worldwide for centuries to power milling and industrial operations. Today, electricity generated from water is the second largest supply of energy used in the world after fossil-based fuels.

Hydropower systems use the energy of falling water from streams or rivers to power turbines and generate electricity. Mountainous areas with swift flowing rivers are particularly suited for hydropower development. Because river flow changes little over the course of a day, these systems seldom need batteries to store energy. When energy storage is needed, water can be held in reservoirs and released to meet periods of high demand.

In the Philippines, Central America, India, Brazil, and Indonesia, mini- (less than 1,000 kW generating capacity) and small-hydropower (less than 10 MW generating capacity) projects generate energy to sell to national electric grids. Micro-hydropower systems, those that generate less than 100 kW, use the water power of streams to bring electricity to isolated villages around the world.

For just \$20,000, community organizations working with Winrock can install and operate a micro-hydro generator large enough to serve 100 households in just three months. Recent technological developments have brought down the cost of smaller units to make them competitive on a per unit basis with energy supplied by large-scale hydropower projects. Where resources exist, hydropower is often the least expensive source of renewable energy.

WIND – Wind is created when warm air, heated by the sun, rises and cool air rushes in to fill its place.

Wind resources are plentiful near coastal and mountain areas, some of the most difficult and expensive places to reach with an electrical grid. There are three components of wind that determine its viability as a renewable energy source: wind speed, air density, and wind turbulence. Wind patterns and distribution can be mapped using weather data, meteorological analysis, and global information systems (GIS) models to determine locations suitable for wind systems.

Wind energy systems generate mechanical or electrical energy. Mechanical energy is used most often for pumping water (via wind-driven pumps). Electric energy is used to drive turbines that generate electricity for homes and

businesses and for sale to utilities. Wind turbines look very similar to windmills, but they are designed using three-dimensional aerodynamics to optimize the amount of wind captured by the blades. Part of that wind power rotates a shaft that is connected to an electrical generator. Wind farms – large plots with up to hundreds of wind turbines – produce power for utility companies.

Winrock is helping individuals and communities install wind turbines that cost as little as \$1200 each, often bringing the first electric power to entire regions. These turbines can be assembled and begin delivering electricity in just a few weeks.

GEOTHERMAL – Geothermal energy comes from the continually produced heat within the earth that is brought to the surface as hot water or steam. Nearly half of the world’s developing countries have geothermal resources. Geothermal energy provides a clean, reliable, sustainable heat source for

- generation of electricity using modular power plants that range in size from a few kW to more than 100 MW;
- direct uses such as food processing, aquaculture, heating homes, buildings, spas, greenhouses, and other commercial uses;

Currently, the worldwide installed geothermal power generation capacity is about 8,000 MW. Geothermal power plants tend to be quite reliable and operate at high capacity factors, typically greater than 95%. Geothermal power plants require relatively little land, so that other land uses can mingle with geothermal plants with little interference.

BIOMASS – Biomass includes all organic plant materials, both cultivated and uncultivated (trees, grasses, crops), and organic wastes produced by humans and animals. Biopower (biomass-to-electricity power generation) provides about 10 GW (1000 MW) of installed capacity in the U.S. and is the single largest source of non-hydro renewable electricity. Biomass is converted to electricity by direct combustion in boilers that produce high-pressure steam to turn turbines. These systems are similar to common coal-fired power systems, but smaller, usually less than 50 MW. Winrock International’s promotion of biomass energy systems since 1989 has brought 300 MW of electricity to millions around the world, mostly in developing countries.

Worldwide, biomass ranks fourth as an energy source, providing approximately 14 percent of the world's energy needs. In developing countries, biomass energy accounts for about 35 percent of the energy used where in rural areas, this may be the only accessible and affordable source of energy for cooking and heating purposes.

Most developing countries located in the tropics grow agricultural crops that produce large amounts of waste – leaves, stalks and stems. These crop residues, usually burned in open fields, can be burned in biopower systems to produce electricity or heat, or converted to liquid or gaseous fuels. Bagasse, which is sugar cane processing waste, is used extensively to generate electricity to support sugar mill operations. Innovations today are enabling these mills to use biomass energy more efficiently and sell excess power to nearby towns, villages, and utility grids. Converting existing biomass resources to electricity or liquid fuels could increase farmer incomes and allow more rural households to switch to cleaner methods for cooking.

Liquid fuels from biomass are produced by fermenting sugars contained in plant material to produce ethanol. This fuel can be used to operate a variety of equipment and machines.

Animal wastes can be anaerobically digested to create methane gas for heating or electricity production. Many small, biogas-powered systems are in use today throughout the developing world. Small modular bioenergy conversion systems in the kilowatt production range are today being developed to produce electricity for remote rural readily available biomass.

The Cost of Renewable Energy

Prices of renewable energy systems have dropped substantially over the last two decades. Technology continues to improve and prices will continue to fall as production capacity of renewable energy systems expands to meet demand.

Rural energy services can be considered in two categories: basic energy for household use and productive energy for creating employment and income opportunities. Both categories of service are important to improved quality of life in rural areas.

On average, large renewable energy systems powered by wind, water, geothermal, or biomass sources can provide 100 W of electric energy at an installation cost of about \$250 per household (five family members) or about \$50 per person. Solar-powered systems can generate 25 W of power for the same cost. (The per watt cost of an entire solar PV system now costs from \$8 to \$40 per peak watt depending on the particular market. The analysis used in this report assumes the average cost of home PV systems to be around \$10 per peak watt, easily achievable today in countries where tariffs are low.) Variations in household size, types of equipment, and usage affect the amount of electricity generated and its price.

One attractive feature of solar energy systems is that they can deliver small amounts of power at relatively low cost. In contrast, connecting an isolated home to the grid or purchasing a diesel engine with a generator both require relatively large initial capital investment.

The total investment to electrify the 500 million families unlikely to be reached in the next 25 years by electrical grids using renewable systems is estimated at \$125 billion. This estimate is based on population growth and average costs per family for solar systems as noted above. While these numbers may appear large, they represent only a tiny percentage of the total investment that will be made to increase power capacity around the globe.

Table 2 presents one possible scenario for increasing power generated by renewable sources. Substantial contributions from renewables are possible without extraordinary increases in manufacturing capacity.

Table 2. Renewable Energy Targets and Growth Rates

Source	1990 Primary Energy-EJ	2025 Primary Energy-EJ	2050 Primary Energy-EJ	Avg. Annual Growth 1990-2025
Hydroelectric Geothermal	28.7	31.8	31.5	<1%
Biomass	3.3	74.4	181.4	9%
Intermittent Renewables	0.0655	37.1	61.0	20%
PV	0.0065	18.5	36.6	25%
Solar Thermal	0.009	3.7	6.1	19%
Wind	0.050	14.9	18.3	18%
Other	0	0	37.8	N/A
Total Renewables	32.0	143.3	311.7	5%

Source: Gerald W. Braun, Director of Business Development, Solarex, a business unit of Amoco/Enron Solar.

Studies of solar lighting programs show that the first few watts of electricity are very important, and the rural poor are prepared to spend a tremendous percentage of their annual incomes on it – averaging from near 75 percent up to 200 percent in some cases. The more affluent purchase roughly the same size systems as the less affluent (Acker, Kammen 1996).

“From field experience, Winrock knows rural people in developing countries want electricity and are willing to pay for it. Historically, subsidy programs have failed to deliver energy systems that work and have undermined commercial markets. Strategies for electrification succeed when local people contribute financially and determine how they want to use power. Projects are even more successful when there is access to credit for equipment. Renewable electricity can expand options for rural employment and income.”

– John Kadyszewski, program leader,
Winrock International’s renewable energy team

Rural people already are spending a lot of money each month on a variety of commercial energy sources: candles and kerosene for lighting, and dry cell batteries for transistor radios and flashlights. In some low- and middle-income countries, it is not unusual for more than 50 percent of the population in non-electrified areas to spend in excess of \$6 a month on various energy sources. Ironically, the poorest people pay the highest per unit energy costs. Dry cell batteries, for example, supply energy at a cost several hundred times higher than most renewable energy systems. Many rural people can pay for renewable energy systems without increasing their present monthly expenditure and receive much higher quality services.

A small percentage of rural people in developing countries, generally less than 5 percent, are able to pay cash to purchase energy systems. A much larger group is able to buy systems if financing systems are available. Loans and leasing agreements are responsible for increasing the number of people who can afford energy systems to more than 50 percent in some communities.

Income from tea and coffee exports has boosted Kenya's rural PV market, for example, which has continued to expand even when the nation's economy has suffered. Analysts have directly attributed the growth of the solar technology market to the steady performance of the rural economy (Hankins 1994 p 5, Acker and Kammen p 85).

These systems can be paid for not by subsidies but by the beneficiaries themselves. Frequently, increases in productivity brought by electricity more than pay for the service. In some cases, payment comes from other economic activities. Regardless of the circumstance, renewable energy systems must be commercially available if this technology is to receive global attention.

Given a choice, rural people are willing to spend a large percentage of their income to have power for household or business uses or for water and irrigation.

Financing & Credit

The availability of renewable energy systems, like other products, depends on market demand to drive production. Producers must recognize the tremendous potential that exists in unelectrified rural areas, and buyers need to know that products are available and what those products can do. Credit and financing for

both individuals and commercial producers is critically important to make renewable energy technology a viable option for electrification.

At the Business Level – In the past 20 years, funding for renewable energy projects has increased because entrepreneurs and end users have been willing to invest. Also, in the last few years, multilateral development banks, most notably the World Bank, have begun to make financing available for renewable energy products and services. However, access to credit and financing is an ongoing problem at every level that interrupts design, production, and system sales.

The cost of identifying and evaluating opportunities and preparing renewable energy projects for financing and implementation varies little between small and large projects. However, these costs are disproportionately high when compared with similar traditional business transactions. The relatively high cost and difficulty in securing financing for commercial renewable energy ventures is a deterrent for many companies.

One way to mitigate the commercial risks of renewable energy project development is to lower the transaction costs and provide seed capital to support specific projects. Winrock works to this end by establishing or assisting organizations in making credit and financing possible.

In the Philippines, Winrock helped launch Preferred Energy Inc. (PEI), a nonprofit organization, to stimulate private sector investments in renewable energy projects. Among other activities, PEI manages a capital investment fund that can be used for debt or equity financing of renewable energy projects. It provides Pre-Investment Cost-Share (PICS) loans to cover initial project development needs.

Yayasan Bina Usaha Lingkungan (YBUL), an NGO in Jakarta that also serves as Winrock's Renewable Energy Project Support Office, specializes in renewable energy, private power development, and environmental activities. It identifies projects and links developers to potential financing sources and manages a refundable grant program that covers up to 50 percent of renewable energy project study costs. Consulting services and technical assistance provided by YBUL give entrepreneurs a place to go for help. The organization has been successful in building the confidence of lending institutions to make loans to environmental businesses and has assisted environmentally-oriented projects totaling \$6.5 million.

In 1990, recognizing that the failure of the developing world's financial markets to provide long-term debt or equity financing was impeding the growth or formation of renewable energy businesses, Winrock formed the Environmental Enterprises Assistance Fund (EEAF). Today the fund is an established specialist that provides debt and equity financing to environmental entrepreneurs in renewable energy and other environmentally beneficial industries in Latin America, Indonesia, and the Philippines. It has offices in the United States, Costa Rica, and Indonesia.

After developing a track record of direct investments (more than 20 investments in eight countries), EEAF identified the opportunity to form larger investment funds to attract even more capital. Such funds encourage participation of institutions that would not likely support smaller projects on an individual basis, due to unfamiliarity with the industry and high transaction costs.

In Central America, EEAF and its local subsidiary, Empresas Ambientales de Centro America, operate the developing world's first small business venture capital fund for the environment. Capitalized at nearly \$10 million, Corporacion Financiera Ambiental (CFA) is a model for creating sustainable development investment funds. To date, it has approved eight investments totaling \$2.5 million. These include a high head hydro installation in Costa Rica, solar leasing in Honduras, and oil recycling in Panama.

At the Individual Level – Credit to offset the relatively high initial costs of renewable stand-alone systems (compared to virtually free connection to an electric grid) is a long-standing problem in developing countries. But, for rural families who want electricity, a small loan spread over two or three years can make a renewable energy home system possible.

Rural people are not only willing to pay for energy, but the electricity that renewable systems generate can make payback easier. One example is Shivaram Gowda, a retired schoolteacher in Jalsoor, India. Gowda uses his courtyard for peeling betel nuts during the evening. The courtyard was lit by kerosene lamps, which provided poor light and limited work hours. When Gowda purchased and installed a home PV system, he was able to work longer hours and increase his income-generating business.

Enersol Associates supplies PV lighting equipment to rural areas of Guatemala in collaboration with a local development organization, AHDEJUMUR. That

partnership includes technical assistance, training, and a credit program for solar systems. Jose Luiz Fernandez borrowed from AHDEJUMUR to buy electrical equipment and to finance systems for his clients who can't pay the typical up-front cost of \$500 to \$700.

“There are a lot of small-scale cattle farmers and coffee growers who have the ability to invest in solar electricity, yet the majority still need some form of credit. With AHDEJUMUR offering financing, my client base is growing and so is awareness of solar electricity.”

– Jose Fernandez, solar system vendor

The Advantages of Renewable Energy

Small-scale renewable energy systems hold the electrical answer for millions around the world. These systems can serve groups as small as a single family or as large as a village, and they generate electricity from a wide variety of renewable, non-polluting power sources.

Renewable energy resources are locally available, as opposed to fossil fuels (coal and oil-based products) that have to be imported and transported to users. Renewable energy sources are abundant (sunlight, water, wind), self-generating, and free. They are not subject to the fluctuations in price and availability common to fossil fuels. Renewable energy systems involve a one-time transportation and installation cost and, when installed, supply reliable electricity. Renewable energy technologies are flexible, modular, and require a short lead time for start-up and operation.

Improving Quality of Life and Standard of Living

Dependable electricity improves the quality of life and economic development. It supports health care, education, and community services. Irrigation extends the growing season, enhances crop performance, and boosts productivity and sales. Electricity opens the door to value-added processing of agricultural goods and community products.

Wind and solar energy can provide power for irrigation to increase the productivity of cultivated land and reduce labor. Lighting allows people to extend their productive hours, redirect time to personal enrichment, or pursue production of handicrafts or other products for sale. Electricity can be used to add value to local agricultural products through milling, processing, drying, baking, distilling, and pasteurizing. Adding value to local products gives rural communities an opportunity to retain more income from agriculture and expand production without jeopardizing the environment.

The task of carrying water often falls to women and children. When they don't have to spend hours each day carrying water, they can use their time for more productive and enriching activities. On Sumba, one of the 13,670 islands that comprise Indonesia, a family of onion farmers devoted 16 hours of labor per day carrying water by hand to irrigate their fields, or a total of more than 1,000 hours

of irrigation labor alone to harvest a single crop. Winrock assisted in installing a small wind power system in the village to operate a water pump. The family paid for the water they used, which helped offset the cost of the wind generator and equipment. The electric pump cut the number of hours the family had to carry water to just 100 hours per season, less than one-tenth the time and backbreaking labor than before. As a result, the family has been able to expand its farm to produce more food, and now has the time to invest in other income-generating activities. The 14-year-old son may return to school.

Raul Torche is a young coffee farmer and storekeeper who lives in the village of El Provenir in Honduras. His village purchased a diesel generator, but was unable to keep it running. So Torche invested in a 40 W PV electrification system for his home and store. The system powers two fluorescent and three low-wattage incandescent lights, replacing kerosene lamps and batteries that can cost rural Hondurans as much as \$20 per month.

Because the light attracts customers, Torche considers the system a vast improvement for his business. Electricity is particularly important to rural storekeepers like Torche, who otherwise are forced to close their stores at sundown. Longer store hours mean more convenience for local customers and more sales for shop owners.

Renewable energy and the reliable, sustainable, and affordable electricity it provides is essential for growth of rural industries and businesses, which bring jobs and income potential to rural areas. Winrock works with organizations and communities to ensure that renewable energy systems support local needs and can be maintained in the future.

Winrock acts as a catalyst. It assists governments, private enterprises, NGOs, and international institutions in developing replicable projects that bring electricity to the poor. Winrock does not sell technology, but rather links demand for electricity with suppliers of renewable energy systems. It focuses on developing policy, assessing renewable resources, and removing barriers that impede system development and use of these sustainable, non-polluting resources.

Natural Resource Management

The future of the planet rests on the ability of populations to manage and conserve resources. Most rural populations primarily depend on agriculture for their food and income. When existing farms can no longer support them and off-farm employment is not available, farmers begin to cultivate marginal lands. Expanding use of marginal lands causes soil degradation and erosion, further reducing productivity and perpetuating the search for new farm land. It also results in degradation of water and habitat. More intensive use of land already in cultivation and the development of off-farm income-generating activities are effective ways for rural people to break the cycle of poverty and environmental degradation.

Growing populations place greater pressure on natural resources. To sustain larger populations, more efficient ways of using natural resources must be developed. Currently, the largest source of energy for rural populations is biomass, but it is used inefficiently. Most is consumed in crude stoves to prepare daily meals and results in negative health impacts.

Using the existing biomass resources more efficiently can be a first step to increased incomes. For example, Winrock has worked with the sugar industry in Thailand, the Philippines, India, and Brazil to develop more advanced conversion systems for the residues of sugar cane production and processing. Selling residues to energy facilities can increase farmer income and produce new employment opportunities for operating and maintaining the trucks and equipment used for collection.

Not only do Winrock projects focus on turning crop and wood processing wastes into energy, and in so doing reduce the burden of these wastes, but Winrock also has developed methods and procedures for monitoring the amount of carbon captured from the atmosphere by vegetation. Careful management of these natural resources can be an important step in managing carbon in the atmosphere produced by burning fossil fuels until the next generation of cleaner technology is ready. Developing and using tools for monitoring land use practices will also help build local understanding and capacity for managing natural resources.

Renewable energy systems bring electricity to rural areas much faster than extension of conventional utility grids and do so without adding greenhouse gases to the environment.

A Size for Every Need

Small renewable energy (mini-power) systems employ a variety of technologies and vary in generating capacity. They range from solar PV systems that can produce electricity for a single family to wind-powered irrigation systems shared by groups of farmers. Micro-hydropower units generate electricity for entire communities, while large biomass, geothermal, wind, or small hydropower systems generate enough power to supply regional or national grids. With recent advances in technology and continuing reduction in prices, mini-power systems are now available to millions who have little opportunity to be connected to national grids.

Power Where It's Needed

Winrock believes that using electrical grids to bring power to rural areas is no longer the preferred solution to meet the electricity needs of rural populations because renewable energy systems will usually be more cost effective and accessible. The costs of extending power lines to the thousands of villages and isolated farms currently without power makes grid expansion tremendously inefficient in its use of capital. In addition, central grids often rely on unsustainable, polluting, and expensive power sources such as oil and coal.

Investment in a rural infrastructure capable of delivering decentralized energy services will also create the capacity to apply the new generation of decentralized technologies currently being developed. It will bring access to communications and information critical to the participation of rural people in the global economy.

Single-family renewable energy systems provide enough power for lights, a small television or radio, and perhaps another household appliance. These systems generate from 15 to 100 W of electricity. A 50 Wp solar system can power a sewing machine, increasing the productivity of its owner. A home with a 50 Wp solar panel will use on average around 200 Wh a day. This compares to around 29,000 Wh used by an average US household per day. Single-family wind and hydropower units also are available. These systems generate from 50

W up to 1 kW and cater to the needs of larger households and commercial establishments.

Mid-size renewable energy systems provide power for large-scale uses. Wind systems of 2 to 10 kW are used to pump water or make ice. Solar water pumping systems are rated from a few hundred watts to a few kilowatts. Solar generators of this size often operate remote telecommunication stations, refrigerators, and institutional lighting.

Solar, wind, and hydropower systems that generate from 5 kW to a few hundred kilowatts are used for village lighting and to power agricultural mills, saw mills, coffee processing operations, ovens, and cooling vats.

"Renewable energy is locally available and sustainable. Fossil fuels are fixed stock; they are finite. Sustainability is linked with renewability. Renewable resources exist where electric power is needed. All we have to do is tap into them."

– John Kadyszewski

Renewable energy systems have some strong advantages. In many cases, they bring the cheapest electricity to rural areas. In Kenya, researchers have found that solar power becomes more cost effective than electricity supplied by the national grid when power lines are 9 km or further away (Acker and Kammen 1996). Studies report that up to 40 percent of the Kenyan home PV systems are installed within 15 km of the electric grid. In Nepal, it is less expensive to generate and distribute 50 kW of power to 400 houses using an isolated mini-grid than to extend the transmission line just 10 km from the national grid.

Renewable energy systems provide opportunities for mobilizing private capital. Solar home systems are generally privately owned. Micro-hydropower systems usually are owned jointly by the users or by an entrepreneur who then sells services. Attracting investment from entrepreneurs and consumers means that substantially more resources are available for electrification. Organization and management of these operations is more streamlined.

Harvesting Energy

Electricity under traditional electrification schemes is thought of as a commodity that originates in urban centers and flows out to rural areas. The development and use of renewable energy has demonstrated that resources found in rural areas can be used in those areas to generate electricity. In the future, rural areas may be seen as places where energy can be collected for transmission to urban centers.

Harvesting renewable resources can provide new income for rural populations. Locally produced electricity can be used to add value to existing products or to make new goods. When enough electricity can be generated locally to justify the cost of connecting to the grid, it can be sold to electric utilities. Renewable energy sources best suited to energy sales to the grid are co-generation from biomass, small hydropower, geothermal, and wind energy.

In the developing world, the benefits of harvesting renewable energy in rural areas are abundant.

"If the Winrock vision can be realized, rural areas will be exporting renewably-generated energy to urban centers, the reverse of what is happening today. Rural people will be harvesting energy like they now harvest crops, and sending it to cities."

– John Kadyszewski

Winrock's Renewable Energy Strategy

Getting renewably generated electricity to the millions who need power poses many challenges:

- renewable energy technology often is not recognized as a viable alternative by government, business, and individuals within developing countries
 - government policies and business practices are designed to support traditional utility systems
 - without established markets, it is difficult to attract commercial renewable energy service and equipment providers
 - financing mechanisms that will help rural people purchase equipment are rare
 - support for entrepreneurs or businesses interested in developing renewable energy projects from both the private and public sectors is limited
 - in-country experience for design, installation, service, and maintenance of renewable energy systems is weak

There is no better way to create partnerships and collaboration and lay the foundation for long-term success than through participatory development, the process that involves local people in determining needs, setting priorities, and planning for the future.

Winrock International's renewable energy strategy addresses four points in its programs to bring electricity to rural people and establish long-term mechanisms to promote and support the use of renewable energy.

Building Local Capacity – Problems require local solutions. Winrock is training local organizations so they can maintain and expand sustainable energy programs. Winrock also integrates renewable power concepts with other rural development programs – water and forest management, agricultural production, human resource development, rural employment and enterprise development – which will make rural regions healthy and economically productive places to live.

“Developing human capacity and creating systems through which energy can be delivered are critical components of the clean energy revolution.”

– John Kadyszewski

Innovation – Technology changes quickly and new technology brings new ways to solve problems. Winrock seeks to bring relevant new technology to rural areas and to make rural markets more visible to companies developing the next generation of technology. Targeted innovations combined with people who know how to apply them can transform rural communities.

Winrock brings its experience and approach to the attention of potential sources of public and private resources. By working with local partners to implement model projects that illustrate the potential synergy between the development of new products, improved rural services, and private profits, Winrock creates positive momentum and attracts capital to the rural energy sector.

Methods and technologies for supplying energy and related services are evolving rapidly. Many will fit rural markets without adaptation, and other technologies will be adapted if private companies see the opportunity for sales. One good example of new technology that is transforming rural areas is wireless communications. Geographic Information System technology is also bringing change.

Financing & Credit – Investment capital is one of the scarcest resources in developing countries. Long-term capital is hard to find, particularly for equity investments. Winrock actively works to mobilize capital to assist private developers in preparing and structuring privately funded renewable energy projects. In 1991, Winrock helped launch the Environmental Enterprises Assistance Fund, which has attracted more than \$20 million to environmental businesses in the developing world. Winrock also is working with the World Bank and other financial institutions to increase financing access to local business, NGOs, and end-users. Winrock has helped establish funds to finance renewable energy systems in the Philippines, India, Indonesia, and the Dominican Republic which provide limited loan and equity funds for projects. Within national programs, Winrock and its network of Renewable Energy Project Support Offices also have helped establish revolving loan funds with local NGOs and have provided working capital to local renewable energy businesses. At the village level, revolving loan programs give individuals the money they need to purchase equipment.

Markets & Commercialization – There is a much stronger market in the unelectrified areas of developing countries for renewable energy technologies than in the industrialized countries where most areas are already electrified and where utilities have access to cheaper sources of energy and can provide electricity at a lower rate. As renewable energy technologies evolve and prove themselves in international markets, prices will drop, making them competitive with other energy sources that supply power grids in both emerging nations and developed countries.

"Most renewable energy technology comes from industrialized countries, but renewable systems are undergoing their true test as practical alternatives in developing countries, an experience that could prove valuable in the future to the entire world."

– John Kadyszewski

Few renewable energy equipment and service suppliers are aware of the tremendous potential of millions of customers who have little contact with the formal market economy. Communities, NGOs and local entrepreneurs can aggregate this demand to attract suppliers of much-needed services.

"The private sector needs to be recognized as a critical partner in [developing country] rural development, if we hope to accelerate the pace at which rural people can obtain access to energy services."

– John Kadyszewski

Governments need policies that promote investment and open access to resource information and rural markets. They also need to set clear goals for the economic development of rural regions. Winrock, in partnership with national and local leaders, works to develop and implement policy changes to allow private companies to sell power, augmenting the limited resources of governments and utilities.

The International REPSO Network

Winrock's international network of Renewable Energy Project Support Offices (REPSOs) is part of a strategy to help local people find appropriate and environmentally sustainable solutions to their energy and income needs. These

offices, managed as local organizations in coordination with Winrock, foster cooperation between government agencies, private enterprises, nonprofit organizations, and communities in common pursuit of harnessing proven technologies for sustainable energy development.

Each REPSO provides technical and financial support services to small businesses, NGOs, communities, and others to promote development of renewable energy programs, equipment, and services. Offices operate in Brazil, Guatemala, India, Indonesia, and the Philippines, and are being developed in China, Mexico, the Dominican Republic, Nepal, and South Africa.

The network functions as a conduit between local project developers and commercially proven technologies and services. It serves industry by identifying new markets and development opportunities, sharing information, and promoting local expertise. The REPSO network is an effective vehicle for matching the global interests of the renewable energy industry with the specific needs of the numerous rural populations without electrical services in the developing world.

BRAZIL – Winrock established REPSO Brazil in Salvador as the fifth office in the REPSO network. The Brazil REPSO serves all of Brazil, but focuses on the northeastern region where cyclical drought and migration are coupled with plentiful renewable resources – solar radiation and wind.

REPSO Brazil works on a large scale within the sugar and forest product industries. A cost-share program for pre-investment studies allows industry to analyze the energy needs of their companies, explore renewable technology alternatives, and determine the finances they will need to make use of renewable energy resources. Small-scale projects support wind, solar, and small hydro rural electrification initiatives with organizations and communities.

The REPSO collaborates with the renewable energy industry, local NGOs, ABEER (the renewable energy trade association for Brazil), state utilities, the Brazilian Ministry of Mines and Energy, the Ministry of Science and Technology, CEPEL (the research arm of the electrical power industry in Brazil), ELECTROBRAS (the government-owned electrical utility), universities, and other entities.

Brazil's Amazon rainforest is an icon for environmental preservation and

sustainable rural development. The Brazil REPSO has been instrumental in formation of the Amazonian Network for Renewable Energy which will not only promote renewable energy use but will work with local people to help manage and preserve this rich natural resource.

“There is no shortage of funding for renewable energy projects for Brazil, and renewable energy has reached the level of federal and state government. But there is a gap between these levels and the community level – REPSO can be the catalyst between these extremes.”

– *Oswaldo Soliano Pereira, manager of REPSO Brazil*

CENTRAL AMERICA – Fundación Solar, an organization founded in Guatemala with Winrock’s assistance, is actively meeting the demand for electricity in remote areas as REPSO Central America.

Fundación Solar’s energy experts assess renewable energy resources across Central America, determine if populations are willing to pay for electricity, and evaluate the type of power generation that is most appropriate for each site. The organization works with the private sector to buy equipment, and with private organizations to operate and service the systems once a project is complete.

Fundación Solar’s goal is to have team members work their way methodically through Central America, bringing access to electricity to everyone. It introduces decentralized renewable energy generation systems in select communities, creates enterprise financing entities that make these systems affordable, and establishes programs that promote productive uses of electricity to build the economic power of rural villagers. The REPSO is active both in large projects that have a potential for grid connection and in village-level electrification and illumination programs.

Fundación Solar/REPSO Central America has worked on energy issues including decentralization, privatization, tariff and institutional reforms, utility efficiency, and strategies to reduce the costs and increase the benefits of rural electrification throughout the region.

“The fragile environments of Central American tropical forests and watersheds will not be protected unless rural people have the opportunity to use methods of power that are income generating.”

– Ivan Azurdia, director, new project development, Fundación Solar

INDIA – REPSO India was established in New Delhi to support the commercialization of renewable energy technologies by building the capacity of local organizations to design and implement renewable projects, and transfer market-ready technology. It works with the Indian government and the private sector to improve quality of life, demonstrate technology readiness, and aggregate renewable energy markets.

Sugar cane cogeneration, commercialization of rural solar systems, and private sector participation in small hydropower are among REPSO India’s initiatives. It also provides financial and advisory services, and outreach designed to heighten the profile of renewable energy in India.

REPSO India manages a program designed to build successful models in the private sector that demonstrate commercial applications of renewable energy while improving access to financing and capital, and facilitating renewable energy partnerships.

“The earlier we develop environmentally benign renewable energy, learn to use it, and perfect it, the better it will be for our future generations!”

– Dr. B.S.K. Naidu, Director, REPSO India

INDONESIA – Yayasan Bina Usaha Lingkungan (YBUL) is the Jakarta-based NGO that serves using the name Renewable Energy Network Indonesia (RENI). It works to stimulate the development of environmental-based business in Indonesia, particularly in renewable energy, energy efficiency, ecotourism, sustainable forestry and agriculture, pollution abatement, and recycling.

Activities include management of a refundable grant fund that covers up to 50 percent of feasibility or prefeasibility study costs for renewable energy project

developers. The YBUL also maintains a renewable energy resource center and facilitated the creation of APITENDO, an association of private Indonesian renewable energy companies.

REPSO Indonesia is experienced in policy analysis, financial management, feasibility studies, technical analysis, and training in energy and environmental projects. Grassroots training for local NGOs and village cooperatives provides a direct link to unelectrified rural communities.

“REPSO projects already have encouraged the development and implementation of many renewable energy projects. These projects will greatly increase the number of MW generated by renewable energy in Indonesia and provide a solid foundation for the enormous potential for renewable energy development in the world’s fourth most populous country.”

– *Yani Witjaksono, director, YBUL*

PHILIPPINES – Winrock helped launch Preferred Energy Inc. (PEI), a non-profit organization, to stimulate private sector investments in renewable energy projects in the Philippines. Among other activities, PEI manages a capital investment fund that can be used for debt or equity financing of renewable energy projects.

“We’re helping private developers assess, structure, and finance projects. Catalyzing private sector initiatives, that is, bridging the gap between technology and financing, is critically important to renewable energy commercialization.”

– *Grace Yeneza, Managing Director of PEI*

One of the ways PEI works to bridge this gap is by mitigating the commercial risks of renewable energy projects by lowering the transaction costs of program development and providing seed capital to support specific financially-attractive work.

REPSO Philippines is working with the government of the Philippines to establish a Solar Village Project Loan Fund and a broader Village Power Fund to provide financing for communities and NGOs, and attract additional financing to support its work.

Renewable Energy Solutions to Real Problems

Winrock's renewable energy initiatives focus on countries where large, widely dispersed populations and rural poverty will continue to be a problem for the foreseeable future. Programs already are established in Brazil, Guatemala, India, Indonesia, and the Philippines, and are being developed in China, Mexico, the Dominican Republic, Nepal, and South Africa.

INDONESIA – In 1994, Winrock launched the WIND (Windpower for Islands and Nongovernmental Development) project in Indonesia. The long-term goal is to use renewable wind energy to strengthen the economies of isolated villages, especially on the remote eastern islands. Wind systems now operate on five islands, with 60 percent of the sites pumping water for agricultural uses and the remainder delivering electricity to households. Villagers have been able to expand farming to produce more products for sale, develop small industries, and significantly reduce the labor needed for daily chores.

A typical wind system – a 10 kW wind generator with battery banks and inverters – costs about \$30,000. It serves from 30-35 families, or about 200 people. Communities share the cost of equipment, transmission lines, and use of the service.

Wind powered water systems are more expensive than wind systems for power generation because associated pumps, meters and pipes to carry water are more costly to purchase and install than simple electric lines. These average \$20,000 for the wind generator and an additional \$25,000 for the water system equipment. These systems can meet the irrigation needs of 40 families, or household water supplies for 80 families.

Winrock works with local NGOs that oversee, monitor, and operate the systems, read the meters, coordinate billing, and handle maintenance.

REPSO Indonesia recently awarded a grant to PT Linsing Rens, a local solar equipment dealer, to help develop solar-powered buoys that will be used to replace kerosene lanterns used by local fishermen for night fishing. Previously, buoys were rigged with as many as 12 kerosene lanterns to attract fish to the nets. These buoys were dangerous, sometimes exploding if they became too hot or wet, and used as much as 40 liters of kerosene a night. New solar-powered

buoys use solar panels to charge batteries during the day that will power lanterns at night.

INDIA – India has a strong commitment to renewable energy and its need for electricity is one of the world’s greatest. One-fifth of India’s population live in villages without any electricity, and only about 40 percent of the 950 million Indians live in electrified homes. In addition, the gap between supply and demand for energy for those connected to a grid has been widening sharply since 1993. During peak load hours the shortages have averaged 19 to 20 percent. This means that only 80 percent of the homes that have electricity can have their lights on at one time – and the others are in the dark.

PV units for lighting, water pumping, telecommunications, and other uses are already widespread in India, but most systems are sold with a government subsidy. Winrock is working with the government and with private companies to demonstrate that high quality systems can be sold without subsidy to rural buyers and in much larger quantities. Winrock has supported a private company building a network of solar centers that sell and maintain solar systems in rural areas. Financing is provided through existing banks or directly by the company. The network of solar centers is being expanded as new technicians are trained and as financing becomes available.

India already is the third largest producer of wind power after Germany and the United States, and is investing much more in that technology than any other country. Winrock is working to improve the operating performance of large-scale wind farms in order to produce at least 25 percent more power using existing equipment. India has a wind power generating potential of 20,000 MW, yet currently produces only 900 MW of wind power. If the potential is utilized, enough energy can be produced to energize 40 million homes.

Winrock is improving the efficiency of cogeneration plants that produce energy from crop wastes, especially in the sugar industry. Sugar mill power plants are much bigger systems than wind turbines. They can generate up to 25 MW of surplus electricity, or enough power to serve 50,000 households at 500 W each.

Traditionally, bagasse was burned inefficiently as a waste product and fueled boilers that produced only enough electricity and steam to meet the needs of the sugar mill. Winrock is working with the Indian sugar industry to improve these cogeneration systems so that they are able to generate more power than needed

by the mill. Excess electricity is sold to the central power grid and surrounding communities.

In 1992, Winrock began researching use of sugar cane tops and leaves left in the field to supplement bagasse in the electricity generating process. The goal is to enable mills to produce extra energy year round. Currently, sugar mills generate power during the crushing season, which lasts from five to nine months depending on the weather conditions in a particular region. Storage and use of leaves and stems will enable the sugar mill generators to run longer. If these tests are successful, power generated from existing sugar mills could produce as much as 5 percent of the total national power supply in India.

Some 2,500 locations have been identified as sites for small hydropower projects with generating capacity of up to 3 MW. India estimates that all together these small hydro systems have a potential of generating from 7,500 to 10,000 MW of electricity, equivalent to 12 percent of total generating capacity in the country. Small hydro systems already built by the government generate about 100 MW of power. Winrock believes involving the private sector can accelerate installation of these systems. The first six small hydro projects to be built by the private sector have now negotiated agreements with the utilities, and are arranging financing for their projects.

In Andhra Pradesh, Winrock recently lent financial support to the Centre for World Solidarity to procure and test solar-powered lanterns for trapping agricultural pests. The area, a major agricultural center in south India (producing local produce as well as exports), has experienced several severe pest attacks, the most voracious of which was by the redheaded hairy caterpillar (*Amsacta albistrig*). Damage and near destruction has been caused to Sesamum, castor, groundnut, greengram, jawar, cotton, and pearl millet. Use of pesticides over the last several decades has led to health hazards. Experiments with solar lanterns instead of traditional electrical lights to trap the insect pests are proving successful.

GUATEMALA – Guatemala is the least electrified country in Central America. Fundación Solar, an organization founded with Winrock's assistance in 1994, works to combat this problem. The village of San Buenaventura is far from electric lines. Most of the 350 villagers earn income from growing crops or doing odd jobs. The local electric utility asked villagers if they would be interested in investing in a pilot solar lighting project using PV systems. With REPSO Central America/Fundación Solar support, PV systems were installed in more than 50

households. Villagers are paying for the equipment over time.

Fundación Solar collaborates with the United Nations High Commission on Refugees and the Canadian Center for Studies and International Cooperation to implement renewable energy projects in refugee resettlement communities. Projects have generated electricity to light school and training centers and power battery charging stations and water pumps. For example, 1.375 W of solar energy is powering a water system in Flor del Norte, while 300 W of wind power is lighting a school in Aldea Chacula.

About Winrock International

Winrock International is a private, nonprofit organization that works with people to build a better world – increasing agricultural productivity and rural employment while protecting the environment. Work in five program areas fulfills this mission: Agriculture, Forestry & Natural Resource Management, Leadership & Human Development, Renewable Energy, and Rural Employment & Enterprise Development.

Winrock is headquartered near Morrilton, Arkansas, with an operational center in Arlington, Virginia. Field offices are in Salvador, Brazil; Beijing, China; Manila, the Philippines; and New Delhi, India. Staff implement projects funded by grants, contracts, and contributions from public and private sources in the United States and some 40 countries worldwide.

Headquarters

Morrilton, Arkansas, USA

38 Winrock Drive
Morrilton, AR 72110-9370
Telephone: 501.727.5435
Fax: 501.727.5242
E-mail: information@winrock.org
www.winrock.org

Regional Office

Arlington, Virginia, USA

1611 North Kent Street, Suite 600
Arlington, VA 22209-2134
Telephone: 703.525.9430
Fax: 703.243.1175
E-mail: information@winrock.org

Field Offices

Salvador, Brazil

Av. Luiz Tarquinio Fontes No. 1580
Villas Trade Center
Edf. Villas Empresarial S. 106/107
42.700-000 Lauro de Freitas
Bahia, Brazil
Telephone/Fax: 55.71.379.1759
E-mail: wibrazil@magiclink.com.br

Beijing, China

Institute of Agricultural Economics
Chinese Academy of Agricultural Sciences
(CAAS)
30 Baishiqiao Road
Beijing 100081, People's Republic of China
Telephone/Fax: 86.10.6218.7544
E-mail: chinawi@eastnet.co.cn

New Delhi, India

No. 7 Poorvi Marg,
Vasant Vihar
New Delhi 110057, India
Telephone: 91.11.614.2965
Fax: 91.11.614.6004
E-mail: winrock-delhi@cgnet.com

Manila, Philippines

Post Office Box 12736, Ortigas Center
Pasig City 1600, Philippines
Telephone: 63.2.632.1233
Fax: 63.2.631.2809
E-mail: winrock@mnl.sequel.net

Power – Definitions, Ratings and Consumption

Power is expressed in watts (symbol W), or its multiples: kilowatts (kW), megawatts (MW), or gigawatts (GW).

1 Watt – A small amount of electrical power. Symbol W.

Typical office lighting uses approximately 200 W of power. A TV set uses from around 30 to 100 W. A solar home system for evening lighting might be rated at 50 W.

1 Kilowatt – 1000 Watts. Symbol kW.

Enough electricity to provide lighting for 10 to 20 rural households in a developing country or to power a solar irrigation pump. Or enough electricity to operate a toaster oven or one burner on an electric stove.

1 Megawatt – 1000 kW or 1,000,000 W. Symbol MW.

Electricity to power lights for a town of around 3,000 families in a developing country and some daytime industries such as agricultural mills, sawmills, arc welders, bakery ovens. Also, enough to power a medium-sized factory in the city.

1 Gigawatt – 1,000,000 kW. Symbol GW.

Peak Watts – Symbol Wp.

Maximum power output of a solar panel when the sun is strong.

1 Kilowatt-hour – Sometimes known as one unit of electricity. Symbol kWh.

The energy consumed when 1 kW is used for 1 hour. One kWh on the national grid may be priced somewhere between 5 cents and 15 cents. Similarly Watt-hour (Wh) or megawatt-hour (MWh).

Power Rating

Power rating specifies the size or capacity of a power generating system – a 50 W solar panel, a 10 kW wind turbine generator, a five MW hydropower project, or a 1,000 MW coal-fired power plant.

The higher the rating of a system, the more power it can produce at its highest performance level. A system will produce its rated power when the energy

source reaches the desired capacity – the sun is shining the brightest, the wind is blowing at the desired speed, the required flow of water is available, or the maximum required amount of coal is fed to the power plant.

The power a renewable energy unit will produce depends on the availability of the resource. A 50 W solar panel might produce only 20 W on a cloudy day and no power at night, so its rating is 50 Wp, where the p denotes peak watts, indicating the production capacity when the sun is shining its brightest.

Energy Produced

Energy is the product of power and time. The longer a renewable energy system runs, the more energy it produces. For example, if a 50 W solar panel produced electricity at maximum capacity for six hours a day, it would generate total energy of $50\text{W} \times 6 \text{ hours}$, or 300 **watt-hours** (Wh) of energy.

Energy Consumption

An electrical appliance is rated according to its power demand: a color TV may be rated 100 W, a smaller black and white set may be rated for only 30 W, a regular light bulb might be rated 60 W, and a domestic refrigerator might be rated for 150 W.

The larger the power rating, the greater the demand for energy. The energy consumed by an appliance, on the other hand, depends on its power rating and the amount of time it operates. A 60 W lamp used for 5 hours consumes $60 \text{ W} \times 5 \text{ hours}$, or 300 Wh. An efficient 12 W compact fluorescent lamp produces the same level of lighting as the 60 W light bulb but uses $12 \text{ W} \times 5 \text{ hours}$, or 60 Wh for the same amount of time.

Renewable Energy System Consumption

Rural consumers in developing countries who get their electricity from small (household) renewable energy systems must use their electrical power economically. Electric stoves, washing machines, and even irons use more power than these systems can provide.

Some renewable energy systems generate electricity intermittently: solar systems generate when the sun is shining and wind systems produce electricity when the

wind is blowing. In these instances, batteries are used to store energy for later use. Electricity that has been stored may be used at any rate supported by the system.

Other renewable systems produce energy more regularly and can operate without the need for battery storage. However, since the electricity has not accumulated in a battery, energy can be used only at the rate it is generated. For example, a micro-hydropower system rated at 10 kW without battery storage cannot support an electric draw greater than 10 kW, and no draw when the system is not operating.

Grid Consumption

People with unlimited access to grid-supplied electricity seldom worry about the power ratings of their appliances or when they can use them, or the capacity of their system. People can use as much power as they want and can afford as long as their electrical wiring will support it.

Large electrical grids produce such large amounts of power related to the relatively small needs of a household that their potential often seems endless. But, grid systems can become overloaded just like isolated generating systems. The result is appliances that do not function to their full capacity, power fluctuations, or complete failure resulting in a blackout.

References

Acker, R. and Kammen, D. (1996). The Quiet (Energy) Revolution: Analyzing the Dissemination of Photovoltaic Power Systems in Kenya. *Energy Policy*. Vol. 24, No. 1, pp. 81-111.

Boyle, Godfrey, ed. (1996) *Renewable Energy: Power for a Sustainable Future*. Oxford University Press, Oxford, England.

Braun, Gerald W. *Financing of Renewables: Considerations and Outlook*. Presentation to FINSOL Workshop, June 17, 1998, Albuquerque, NM.

Cabraal, Anil, Mac Cosgrove-Davies, and Loretta Schaeffer. *Best Practices for Photovoltaic Household Electrification Programs, Lessons from Experience in Selected Countries*. World Bank Technical Paper 324. Washington, D.C.

Foley, G. (1995). *Photovoltaic Applications in Rural Areas of the Developing World*. Technical Paper No. 304: Energy Series. World Bank, Washington, D.C.

Geothermal Energy Association. Association brochure, May 1998.

Gregory, J. and McNelis, B (1993). "The Growing Role of Solar Electric Power Production in Developing Countries." *Power Generation Technology*. March.

Hankins, M. (1992). *Photovoltaic Power to the People: The Kenya Case*. UNDP and World Bank Energy Sector Management Assistance Program, Nairobi, Kenya.

Kammen, D.M. (1996). *Household Power in a New Light: Policy Lessons and Questions for Photovoltaic Technology in Africa*.

Shepperd, L.W. and Richards, E.H. (1993). *Solar Photovoltaics for Development Applications* Sandia National Laboratories report for the Department of Energy, Washington, D.C.

World Bank (1996). *Meeting the Challenge for Rural Energy and Development: Rural Energy and Development for Two Billion People*.



Headquarters

Morrilton, Arkansas, USA

38 Winrock Drive, Morrilton, AR 72110-9370

Telephone: 501.727.5435

Fax: 501.727.5242

E-mail: information@winrock.org

www.winrock.org

Regional Office

Arlington, Virginia, USA

1611 North Kent Street, Suite 600

Arlington, VA 22209-2134

Telephone: 703.525.9430

Fax: 703.243.1175

E-mail: information@winrock.org