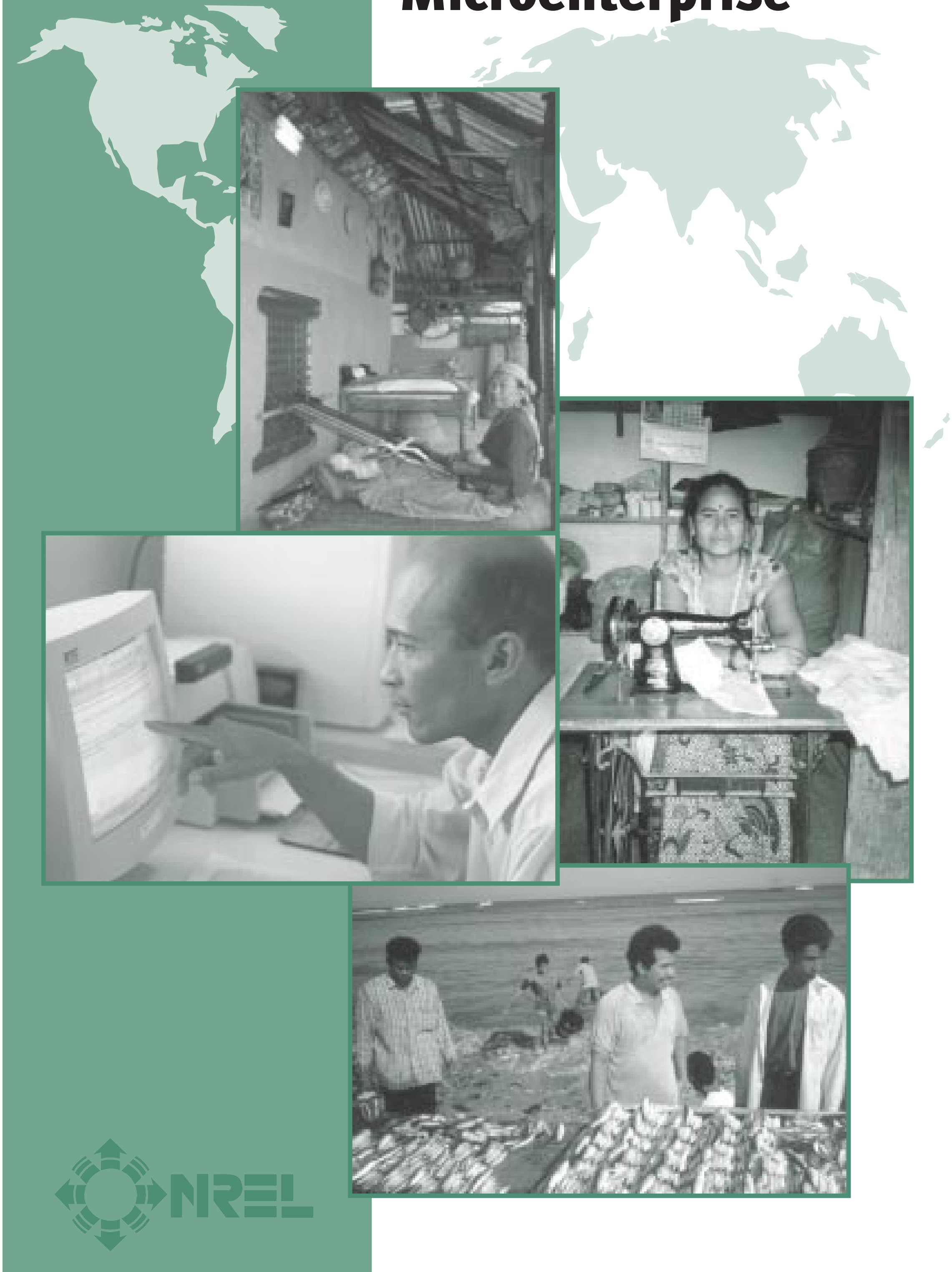
Renewable Energy for Microenterprise



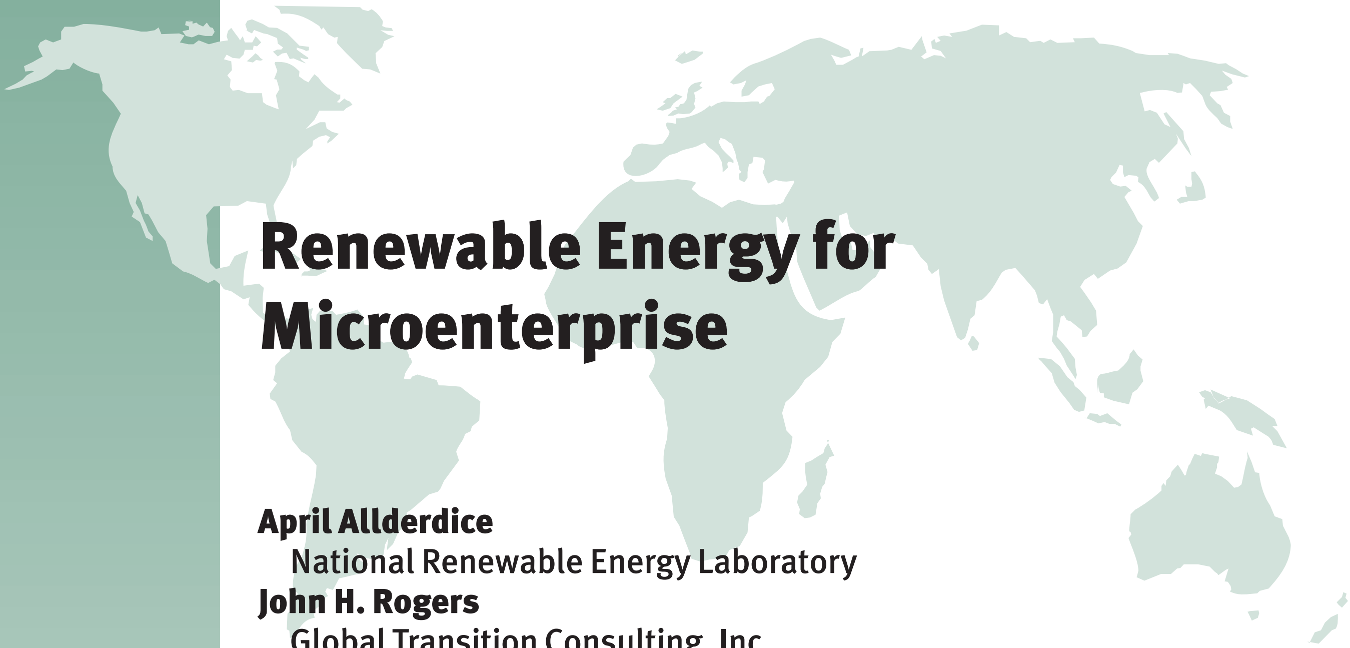
Cover Photos:
Top left: A Nepali woman weaver under a solar-powered light in her home.
(Selco / PIX08143)

Left center: PV powers computers in a rural office in the Dominican Republic.
(Enersol Associates, Inc. / 02618843)

Right, top: A Nepali seamstress uses solar-powered light to extend her working hours into the evening.
(April Allderdice, NREL / PIX07150)

Right, bottom: Indonesian fishermen with catch they store in wind-powered refrigerators.
(Winrock International / 02618848)

Renewable Energy for Microenterprise



Renewable Energy for Microenterprise

April Allderdice
National Renewable Energy Laboratory
John H. Rogers
Global Transition Consulting, Inc.

November 2000

Published by the
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
United States of America

FOREWORD

It has been said that authentic development is where the moral and the material come together; where our compassionate urges to improve the human condition become real through the expansion of commercial practices. In this regard, "Renewable Energy for Microenterprise" is an invaluable resource. Through clear language and compelling examples, this guide demonstrates how sustainable energy sources can literally energize social, economic and political development.

Human history is replete with glaring lessons of how individual prosperity and social equity flow from the efficient application of energy technologies. In an age where poverty remains the norm for millions upon millions of individuals throughout the world, the search for how to generate economic growth takes on an importance unparalleled in its significance.

Amartya Sen, the Nobel laureate economist, persuasively argues that development and freedom are inextricably connected; that the "expansion of freedom is both the primary end and the principal means of development." In this light, this guide is at root, all about liberating the entrepreneurs and their families of the world from the tyrannous yoke of poverty by showing how renewable energy can help power their way to a better quality of life. Such instruction is both noble and necessary.

Those who are familiar with renewable energy technologies and the efforts to commercialize them know that it is the institutional and financing issues that pose the greatest impediments to widespread adoption. The writers of this guide not only explain in clear detail, punctuated with successful real-world examples, the nature of the financial re-engineering required, but skillfully map out the entire social-technological-financial landscape that puts the human element in the foreground where it rightfully belongs.

This guide is dedicated to the proposition that renewable energy technologies provide a critical and catalytic role in the realization of social and economic development. At the U.S. Agency for International Development’s Office of Energy, we are working hard to illuminate the linkages that exist between energy and poverty alleviation, improved health and education services, gender and inter-generational equity, and social justice. Our programs are designed to move energy from the margins to the mainstream of the development dialogue. Through the publication of this guide, the National Renewable Energy Laboratory (NREL) is making a major contribution to this effort of making more visible the central role energy plays in sustainable development.

I congratulate and sincerely thank NREL, the authors, and all who have contributed to making this guide possible. I urge all development practitioners to read it and use it. And most importantly, congratulations to the countless entrepreneurs, past, present, and future, who tirelessly prove that microenterprise initiatives, fueled by renewable energy technologies, produce macro human benefits.

Dr. Griffin Thompson
Director, Office of Energy, Environment, and Technology
United States Agency for International Development

PREFACE

Income generation is one of the keys to improving the quality of life in rural communities. Microenterprise, and the associated microcredit activity, have proven to be enormously successful in unlocking the human capacity in rural villages to provide income, that, in turn, can be used for improving the quality of life in both home and community. Rural economic development is an important national and international priority. However, the availability of electricity to support rural enterprise activities is less than adequate in many countries. In recent years, the development of reasonably priced and reliable renewable energy systems has made it possible to enhance the production and marketing of a variety of these income-generating activities, through the provision of electricity for motive power, lighting, computers, and telecommunications in remote areas. A number of international, national, and local institutions, nongovernmental organizations, foundations, and private companies are supporting the deployment of renewable energy systems in rural communities in the developing world where microenterprise is a national priority.

Because renewable energy is regionally diverse, choosing the appropriate renewable energy system will depend on the needs of particular rural sites. Although photovoltaic (PV) lighting systems have paved the way and are being deployed in many remote communities around the world, other small renewable sources of electricity should be considered. One of the objectives of this guidebook is to expand the remote electricity opportunity beyond PV to areas of good wind or hydro resources. Also, in the near future we expect to see micro-biomass gasification and direct combustion, as well as concentrated solar thermal-electric technologies, become commercial rural options.

The three important factors driving the selection of the appropriate technology are the local natural resource, the size and timing of the electrical loads, and the cost of the various components, including fossil fuel alternatives. This guidebook reviews the considerations and demonstrates the comparisons in the selection of alternative renewable and hybrid systems for powering microenterprise activities.

The National Renewable Energy Laboratory's (NREL's) Village Power Program has commissioned this guidebook to help communicate the appropriate role of renewables in providing rural electricity services for powering rural enterprise. The three primary authors, April Allderdice, John Rogers, and Tony Jimenez, combine the analysis, design, institutional, financial, and deployment experience that has made them such an effective team. This guidebook should prove useful to those stakeholders considering renewables as a serious option for electrifying rural enterprises, and associated rural enterprise zones. It may be useful as well to renewable energy practitioners seeking to define the parameters for designing and deploying their products to meet the needs of rural enterprise.

This is the third in a series of rural applications guidebooks that NREL's Village Power Program has commissioned to couple commercial renewable systems with rural applications, such as water, health clinics, and schools. The guidebooks are complemented by NREL's Village Power Program's application development activities, international pilot projects, and visiting professionals program. For more information on this program, please contact our Web site, http://www.rsvp.nrel.gov/rsvp/.

Larry Flowers
Team Leader, Village Power
National Renewable Energy Laboratory

CONTENTS

HOW TO USE THIS GUIDE

Who Is this Guide for?

This guide is targeted to the many types of microfinance institutions (MFIs) and microenterprise support organizations that are interested in improving the profitability of their members' microenterprises through renewable energy (RE) technologies. In addition, RE suppliers and technical organizations can use this guide to strengthen efforts to incorporate microfinance institutions and practices into rural electrification programs.

What Is the Purpose of this Guide?

This guide will provide readers with a broad understanding of the potential benefits that current RE technologies can offer rural microenterprises. Moreover, it will introduce the institutional approaches that have been developed to make RE technologies accessible to microentrepreneurs and the challenges that these entrepreneurs have encountered. Readers should then be better prepared to assess the energy needs of their clientele and select appropriate technical and institutional approaches to meet those needs.

What Is in this Guide?

This guide gives a broad overview of the relationship between microenterprise, microfinance, and energy, with an emphasis on decentralized RE. Chapter 1 begins with a discussion of the diversity of rural microenterprises and their energy needs, from lighting for artisan tasks and selling during evening hours to powering motors for hulling, grinding, or freezing. This section draws on a body of research that has studied the economic benefits of electrification. Chapter 2, intended for RE practitioners, describes the various types of microenterprise development organizations and programs to assist rural areas of developing countries. This chapter offers an introduction to the main concepts of micro-credit and the MFIs that provide it. Chapter 3 discusses the components of stand-alone RE power systems, including their function, costs, lifetimes, proper operation and maintenance, and limitations. The first section of Chapter 4 contains an overview of life-cycle cost (LCC) analysis, a valuable analytical tool used to compare energy system options. The remainder of the chapter is devoted to discussing the factors that influence the design of stand-alone RE systems for particular applications. Chapters 5 through 7 focus on three institutional approaches that have been used to combine RE technologies with microfinance for the benefit of microentrepreneurs. In the first arrangement, the MFI finances the purchase of a small RE system by a rural microentrepreneur or household. In the second arrangement, an MFI, microenterprise nongovernmental organization (NGO), or strategic partner develops a community-scale facility in which electricity and other services are provided to microentrepreneurs on a fee-for-service basis. In the third arrangement, a credit organization finances a microentrepreneur owning and operating an energy supply business, which may be a retail operation, a battery-charging station (BCS), or a minigrid. This guide presents advantages and disadvantages of each of these institutional approaches, with an emphasis on the experiences of existing programs. Chapter 8 presents five case studies of existing programs and lessons learned. At the back of the guide are a list of references, a bibliography, and a glossary of terms used in this guide.

INTRODUCTION

Microenterprise is alive and thriving in the developing world. During the past decade, the growing success of microfinance as a tool to help alleviate poverty has brought attention to the significance of the microenterprise economy. Microenterprises (i.e., very small businesses) have been increasingly identified as a key component in rural job creation and the raising of income in rural economies.

If the microenterprise, or informal, economy is so vital to rural development, to what extent have past rural electrification programs targeted the microentrepreneur? In the planning process of many rural electrification programs, the existence of rural industry or agricultural electric demand has been a major consideration in setting priorities for grid extensions. This focus generally involves large enterprises rather than the lower-profile microenterprises. Nevertheless, microentrepreneurs have readily taken advantage of rural electrification programs. A study from the Philippines Rural Electrification Program found that about 25% of all "residential" connections were using electrification for some type of income-generating activity. [1]

Although microentrepreneurs can benefit greatly from electrical services, they lack the formal associations, the political connections, and the financial leverage to affect the rural electrification planning process. By representing large numbers of microentrepreneurs, microfinance and microenterprise intermediaries are in a position to challenge this trend. Both in its ability to mobilize the finances of the informal sector and its vision to target income-generating applications of electricity, the microfinance / microenterprise sector has an institutional capacity that can help meet the electrification needs of the rural microentrepreneur. Since the barriers to the utilization of renewable energy in microenterprise are well matched to the capabilities of the microfinance / microenterprise sector, the role of MFIs and microenterprise development organizations in rural renewable energy dissemination will be a major focus of this guidebook.

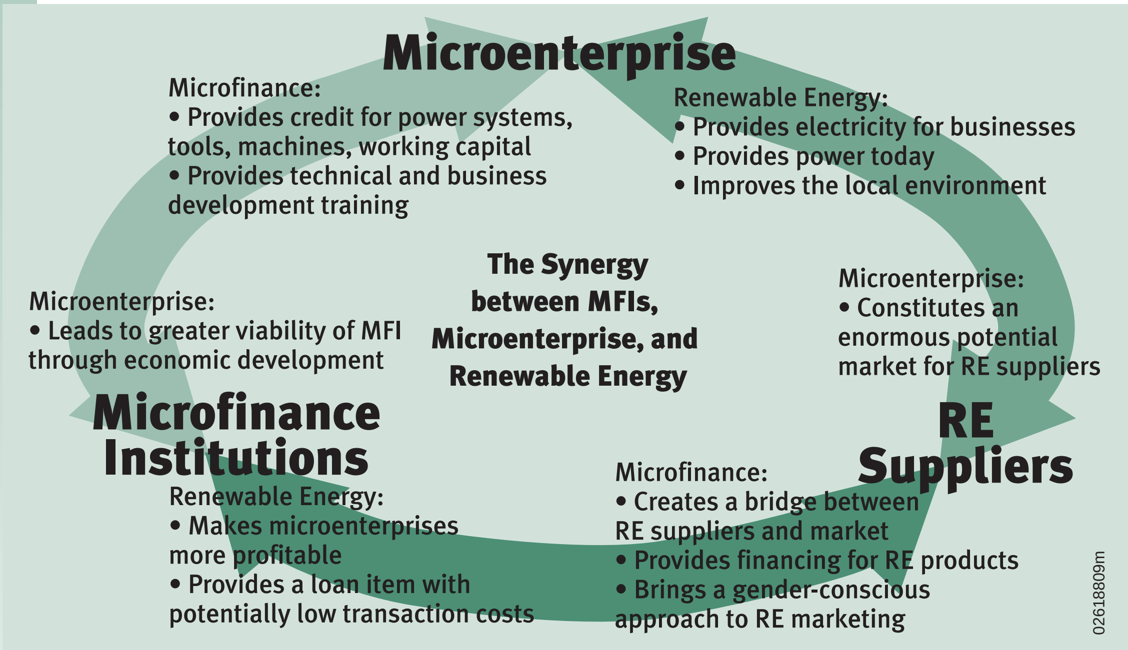


Figure I.1. Graphical representation of the interdependence of microfinance, microenterprise, and renewable energy

The microfinance sector's innovative re-thinking of modern banking has provided lending mechanisms specifically for the microentrepreneur. Spurred by solid successes, funding agencies such as the World Bank's Consultative Group to Assist the Poorest program and the United Nations Development Programme's (UNDP's) Capital Development Fund have emerged to finance the growth of the microenterprise sector. Microfinance institutions are now challenged to funnel these resources as efficiently as possible to their members. This availability of capital, as well as demand for energy from the microenterprises, creates an opportunity for microfinance intermediaries to include loans for energy systems in their portfolios. Indeed, many already do provide loans for diesel or gasoline generators. In many cases, recent technical advances could create an opportunity to substitute cleaner, more cost-effective RE technologies for traditional electrical energy systems.

The renewable energy field has developed an array of rural electrification technologies that, in addition to being cleaner than conventional energy sources, are designed to meet the needs of people without access to grid electricity. The options range from small, predesigned solar and wind system packages that offer a complete basic electrical system (which can often be owned by the microenterprise), to larger solar, wind, micro-hydro, and biomass systems that offer 24-hour, alternating current (AC) electricity for ice-making, milling, and other commercial applications.

The microenterprise development and rural renewable energy supply sectors seem to be highly complementary. Many microenterprises can use electricity to increase their productivity, enhance their local economy, and improve their quality of life. Microfinance institutions find in renewable energy a new loan item that will strengthen their client microenterprises and diversify their own lending portfolios. The renewable energy industry has long suspected that small, distributed users are a potentially large market, but applications have been restricted largely to subsidized government initiatives and small-scale commercial efforts. A lack of adequate delivery capability, particularly for rural credit, has been a barrier to creating programs that are affordable for end users and that ensure cost recovery. Access to end-user financing can open rural microenterprise and household markets for RE technology; there are many successful demonstrations of this all over the world.

Using microfinance as a framework for renewable energy dissemination may have additional benefits beyond end-user finance, such as the following:

- Microenterprise development practitioners can facilitate the business development training that needs to accompany the integration of RE into microenterprises.
- The existing rural networks of microfinance organizations can facilitate promotion and help build credibility for the new technology.
- The microfinance banking and renewable energy sectors each have their own networks of financial intermediaries, which may increase the overall capacity for financing.
- Microfinance institutions often have a gender focus. This may help target RE systems to the needs of women, who constitute a large portion of informal economy entrepreneurs.

Where appropriate energy technologies can help to increase the profitability of microenterprises, the microfinance and renewable energy sectors could be strong allies in facilitating dissemination. However, combining microfinance with rural RE presents several challenges. For example, mismatches can occur between the goals and operating philosophies of the power supplier and the MFI. This guidebook examines such pitfalls and presents actual responses to them drawn from a number of successful pioneering efforts that have combined renewable energy with microenterprise development. This guidebook is intended to encourage and support these efforts to help rural entrepreneurs take advantage of renewable energy technologies.

CHAPTER 1. MICROENTERPRISE AND ELECTRICAL ENERGY

What Is Microenterprise?

A microenterprise is a very small business that produces goods or services for cash income. In general, microenterprises have limited access to capital, have few employees, and are often home-based. Not all microenterprises are family-operated, but when family members do work for the business, they frequently do so without pay. Small cooperatives can also be microenterprises. Microenterprises usually operate in the "informal sector" of a nation's economy, not paying taxes and not being tracked in official government statistics.

Microenterprises may be small and officially invisible, but they are far from insignificant. In Chile, one-fourth of the labor force works in microenterprises; in Columbia, nearly one-half; and in Bolivia, more than one-half of the labor force is estimated to work in microenterprise. From 1992 to 1995, 90% of the new jobs created in Bolivia were in microenterprise and the informal sector. [2]

Rural microenterprises often suffer from the general neglect of rural areas. Infrastructure is usually very limited and characterized by a lack of good roads, inadequate water supply, minimal telecommunications, and electrical distribution supplied only to concentrated population centers. Nevertheless, entrepreneurs sell everything from cow dung to cellular phone time. The very diversity of their activities and the scarcity of their resources cause microenterprises to form a uniquely dynamic engine for rural economic development.

Microenterprise and Electrical Energy

The Electrical Needs of Microentrepreneurs

Access to even limited amounts of electricity for microenterprises in non-grid-connected areas can be important to the establishment and growth of those businesses. Electricity can have positive effects on the following:

- **Operating Hours**—Renewable energy systems can provide lighting to allow microentrepreneurs to extend their working day and generate more income. Mobile solar lanterns make it possible for street vendors to extend their selling hours into the evening. Workshops use electricity from an RE system to extend their hours and increase production.
- **Working Conditions**—Electrical energy from renewable energy systems can offer much cleaner and safer services than traditional energy technologies. An electric fluorescent lamp for area lighting or illumination for particular tasks such as sewing, reading, or writing can be considerably easier to use than a kerosene wick or pressurized gas lamp, eliminating the fear of accident or damage to the home environment from smoke and soot.


Winrock International / 02618850

Figure 1.1. A solar lantern is used for agricultural pest control in India.

- **Consumer Draw**—In unelectrified rural areas, electric lights, fans, radio, or television can all draw people to a common location. Those microenterprises able to access energy in order to

April Allderdice / 02618831

Figure 1.2. In this Bangladeshi carpentry shop, production increased by 200% with an RE system payback of 2 months.

provide an environment more conducive to congregation may profit from increased customer contact and sales.

- **Mechanization/Automation**—Electricity to run a motor for a sewing machine or grain mill can transform a manual subsistence activity into an income-generating enterprise, or help transform a barely viable enterprise into a more sustainable one. Uniform production and higher quality may command a higher price, especially in export markets. Consistent products also serve to establish a regular clientele.

Hugo Arriaza / PIX08140

Figure 1.3. Guatemalan woman in a store powered by a solar system.

- **Product Preservation**—Electricity can help microenterprises tremendously in preserving products for export or retail. Small rural stores can expand their inventory by adding items that need refrigeration. RE-powered icemakers can assist industries such as fishing and produce. Crop drying, by small electric fans that circulate air around a heated surface, can also be used to preserve crops for export.

Winrock International / PIX07889

Figure 1.4. Indonesian fishermen with catch; the fish can be preserved using RE-powered refrigerators.

- **Communications**—RE-operated cellular phones can allow microentrepreneurs to investigate city market conditions before they decide whether to send their product there, and when to send it.

Hugo Arriaza / PIX08141

Figure 1.5. This Guatemalan workshop uses RE.

Inputs		
Blender cost	$	100
Blender O&M	$	1
Blender depreciation	months	36
System cost (prorated)	$	100
System O&M (prorated)	$/month	1
System depreciation	months	120
Battery cost (prorated)	$	20
Battery depreciation	months	24
Labor (prorated)	$/day	2.5
Work schedule	days/mth	22
Raw materials	$/drink	0.20
Selling price	$/drink	0.50
Sales	drinks/day	20

	Monthly
Revenue	
Sales of drinks	220
Expenses	
Cost of goods sold	88.00
Blender depreciation	3.00
Blender O&M	1.00
System depreciation	1.00
System O&M	1.00
Battery depreciation	1.00
Labor	55.00
Total Expenses	**150.00**
Profit/Loss	**71.00**

Enersol Associates, Inc / 02618844

Figure 1.6. This business analysis shows the potential for income generation found in expanding a solar PV system designed for domestic use. Increasing the system size and adding a DC electric blender could allow the home-based enterprise to make a net monthly profit. While this plan is hypothetical, similiar businesses have been operating with solar power in the Dominican Republic.

April Allderdice / PIX07150

Figure 1.7. A Nepali seamstress uses solar light to extend her working hours into the evening.

- **Education**—For many children, especially girls, the lack of electricity translates into a missed opportunity to attend school. Instead, their labor is needed for tasks such as fetching water and fuel during daylight hours. Electricity can both reduce the effort of these menial tasks and provide lighting for classes in the evening.

Microfinance Bank and NGO Offices

In addition to microenterprises, the non-governmental organization offices and micro-finance banks that serve them often need power themselves. Offices can use lights and fans to prolong working hours and relieve eyestrain caused by doing office work in inadequate light.

Enersol Associates, Inc. / 02618830

Figure 1.8. Computers increase capabilities and efficiency in the rural office of the Dominican NGO, ADESOL (see case study, p. 31).

Gradually, some microfinance banks, even in very remote areas, are computerizing their offices and need power sources for this equipment, as well.

Enabling Factors in the Productive Application of Electrical Energy

Although electrical energy can be a powerful enabling tool for microentrepreneurs in rural areas, the impact it can have is mitigated by a number of coexisting conditions. Microentrepreneurs may need support to purchase the appropriate electrical machine that will allow them to take advantage of the electricity. In addition, they may need training or other services to ensure that their utilization of electricity translates into a sustained economic benefit. A program that addresses the obstacles to using electricity to increase income and improve the local economy is called a "productive uses of energy program." Successful productive uses of electricity programs address a number of factors necessary for entrepreneurs to benefit from electrical resources. These factors include the following:

- Reliable and affordable electricity
- The availability of tools and machines for productive applications
- Credit for fixed assets (tools) and working capital
- The human resources necessary to master both the technical and business challenges incurred by a new activity
- A market for increased quality and production. 3

In the institutional approach sections, this guidebook will discuss the ways in which MFIs and microenterprise support organizations can provide a variety of services to enable microentrepreneurs to use renewable energy resources productively.

Hugo Arriaza / 02618837

Hugo Arriaza / 02618838

Figure 1.9. In Guatemala, the National Rural Electric Cooperative Association's productive uses of electricity program features a van equipped with several electrical tools and appliances. Villagers in soon-to-be-electrified areas can try out and ask questions about the equipment. NRECA then facilitates acquisition by putting the end user in touch with credit and equipment suppliers.

CHAPTER 2. MICROFINANCE AND MICROENTERPRISE DEVELOPMENT ORGANIZATIONS

Many organizations have dedicated themselves to supporting microenterprise development through a range of services. Microfinance (the provision of small amounts of credit) in particular has emerged as a significant tool to aid microentrepreneurs who are excluded from the formal banking sector. This section will describe the basic concepts of microfinance banking. It will also present some of the nonfinancial support services an organization may provide, either linked with a credit program or independently. Finally, it will examine how these services relate to renewable energy system finance and energy service provision.

What Is Microfinance?

To bring financial services to the poor, microfinance providers have developed lending mechanisms that do not depend on the collateral, credit history, and loan guarantees that the formal banking sector requires. Microfinance programs can be characterized both by the mechanisms they use to reduce risk and by the populations they target. Some of the more common features of microfinance programs are described below.

April Allderdice / 02618840

Figure 2.1. Microcredit bank members wait for a loan disbursement.

- **Loan Amounts**—Microfinance loans tend to be very small (typically, $50 to $500), although the actual amount varies widely from country to country. By restricting the first loans to small amounts, microfinance schemes target the poor and provide them with a limited scale of financial risk from which to gain experience managing loans. Smaller loans also minimize the risk to the implementing agency by requiring that the borrower build a track record of payment before graduating to larger loans.[4]

After years of experience, some microfinance organizations now offer larger loans ($1,000 to $5,000) to repeat clients with proven credit histories. Raising the ceiling on loans, as both the organization offering a microfinance program and its clients gain experience, can allow or encourage clients to diversify their enterprises. It can also reduce transaction costs and provide higher return for the credit institution. Larger loan sizes for successful microentrepreneurs are in line with the financing of RE systems, which can easily cost from $500 to $5,000 or more.

- **Short-Term Working Capital**—Microfinance loan cycles usually range from four months to one year. Shorter cycles enhance new borrowers' chances of completing the cycle, thus building their confidence. This policy also helps in managing lending risk assumed by the implementing agency.[5]

Loan items can include agricultural materials, livestock, stocks for stores, or raw materials for cottage industries. Some programs also lend for fixed assets such as power tools, vehicles or production machinery. Others have diversified their portfolio to include longer-term loans for housing in rural communities, where microenterprises are often home-based. Thus, housing loans (including home improvement loans) and investments in RE systems for microenterprises can be linked. RE systems can play a significant role in both home improvement and cost reduction (displacing kerosene and dry cells), in addition to enhancing the home-based microenterprise.

- **Repayment Schedules**—Small, frequent payments allow borrowers to repay loans out of their regular incomes and avoid relying on the income generated from a specific investment.[6] Moreover, they encourage the borrower to establish good repayment habits from the outset. This short repayment schedule may be appropriate for RE equipment financing, particularly because traditional energy sources such as candles, kerosene, and dry cells are normally purchased in small quantities on a weekly or even daily basis.

- **Social Collateral**—The group is the fundamental unit of most microfinance schemes. By forming small groups whose members are jointly liable for each individual's loans, microfinance clients create a form of social collateral to substitute for material assets. Different programs devise their own criteria for the composition of peer groups. Usually, each group consists of a small number (e.g., five) of members of the same sex and of a similar age, class, and religion. Single-gender peer groups are more likely to share common goals, needs, and interests, which can facilitate a higher level of solidarity. Women, in particular, are more apt to develop and exercise leadership skills in a group that functions as a source of support and social interaction.[7]

The group in microfinance schemes serves a number of purposes. Compulsory group meetings discourage better-off people from taking loans, thus increasing the funds available for lending to the poor. Most transactions take place in front of the group, which creates accountability for both borrowers and program staff. The transparency prevents staff favoritism in the allocation of credit and makes it immediately apparent when a borrower falls behind in his or her payments. Social pressure to repay a loan may then be exerted on a delinquent member by other members and by the staff. Where groups are formed through self-selection, the individual members effectively screen each other, externalizing a costly operation of the bank. This is especially true in the cases of small solidarity groups.[8]

The group is also the setting for many of the human development processes that accompany microfinance. It creates a social network for women, that often proves conducive to development of leadership skills; the groups can also serve as a classroom where literacy and health education can be provided. The social network could also be valuable for the dissemination of information regarding RE systems and applications.

- **Interest Rates**—Most microfinance programs charge a higher interest rate than the commercial rate. Charging interest rates that cover the full costs of the loan serves to maintain fund levels. This policy is basic for any program that strives for sustainability or financial independence. As these goals are attained, more loans can be dispersed. High interest rates discourage wealthy borrowers from joining microfinance programs. While interest rates for microfinance are high, the rates are usually lower than the alternatives to which the poor often turn. In addition, the reliable availability of financing provides a level of security conducive to making significant capital investments (e.g., in RE systems). For example, a small store owner can retain a lower amount of emergency savings if she knows that in an emergency a loan will be available to meet her needs for working capital.

- **Gender Focus**—Women's reliable repayment records, and the proven application of increased income to directly serve the needs of their children, have resulted in a distinct gender focus in the field of microfinance. The social and economic factors that lead to higher repayment rates by women vary from culture to culture. The social norms of diverse cultures often have a similar effect of causing women to have less mobility, fewer social freedoms, less access to alternative forms of cash, and fewer economic opportunities than men have. Regardless of the cause, the sociological benefits of targeting women for microfinance have been observed worldwide. Many microfinance programs either limit their members to women, or strive to target women in their programs. In linking between renewable energy and microfinance programs, the gender focus represents a challenge and an opportunity to develop products targeted to women customers.

- **Savings**—Clients of microfinance programs often value a safe and easily accessible place to save money. For this reason, a number of microfinance programs facilitate "village banking," whereby a savings component is included within the program structure. Bank Rakyat Indonesia, for example, has 14.5 million deposit accounts and only 2.3 million loan accounts.[9] Rural savings can be a local source of additional capital for lending, and it represents an investment in the long-term sustainability of the microfinance program. Rural savings can also prepare potential users of RE systems for making a substantial downpayment on such a system.

Microfinance and Energy System Financing

Linking microfinance with renewable energy for microenterprise can present challenges to organizations already faced with many difficult tasks. Mismatches may occur between the financing needs of RE systems and established microfinance practices. Some of these potential challenges and mismatches are described next.

Loan Size and Loan-Term Priorities

Loans provided by an MFI may be large enough to finance only the smallest renewable energy systems. Access to capital is one of the key factors that affect a credit institution's priorities and viability. If access to capital is limited, a credit institution may respond by imposing low loan ceilings and short loan terms in order to reach as many customers as possible and meet social-impact goals. This may prevent them from lending the larger amounts often needed for renewable energy systems.


April Allderdice / 02618833

Figure 2-2. Members gather in a microfinance bank office.

Reaching the Poorest Applicants

Although the goal of a microfinance program may be to reach as many members of the poorest social stratum as possible, an institution's financial viability is underpinned by the lower-risk loans it gives to its veteran members. Thus, growth depends on a balance between reaching out to first-time members and building new, larger loan opportunities for existing members.

Energy systems are most likely to be sought by more established members of a microfinance program. These members may already have businesses that could achieve greater profits with electricity, or may already have repaid a loan large enough to have financed an energy system. Also, these members may be more confident, and thus more capable of incorporating a technological change. New members are less likely to have these qualities, and they may have more pressing needs than electrical energy. An energy program that targets very poor or beginning borrowers would have significantly different challenges than one that targets a more experienced group. However, it is important to note that either approach, if implemented well, could serve to meet the microfinance program's goals of client expansion and higher earnings. For more information about designing a program to meet the needs of a particular target audience, refer to the institutional approaches described in Chapters 5, 6, and 7.

Fixed-Asset Lending

Many microfinance programs operate in areas where the legal and regulatory environment is either corrupt or inaccessible to the rural population. Even relatively well-off microfinance customers may turn to alternative credit institutions when they are unable to establish legal ownership of their land or other assets. The social collateral mechanism of microcredit sidesteps the obstacles caused by ineffectual legal networks. Although fixed-asset lending for items such as a renewable energy system offers a degree of self-collateral, these contracts are only valuable where they can be reliably enforced. In uncertain legal environments, warranties, service guarantees, and collateral all must be designed with extra care to minimize the risks to both renewable energy organizations and MFIs.

Microenterprise Support Services

Microenterprise development organizations may offer the following support services to their client microentrepreneurs:

Business Development Training

Programs that are aimed at helping individuals develop a microenterprise often provide technical advice, simple bookkeeping, and business management training. TechnoServe, Inc., is one firm that operates a rural business development and credit program. The company uses a participatory training approach that supports and builds democratic pluralism and leads to local self-reliance and equality. TechnoServe mobilizes individual talent while providing training and management assistance in all aspects of business development, including production, marketing, administration, finance, and accounting.

Infrastructure and Market Development

NGOs can be helpful in addressing macro-issues in the business environment of the microentrepreneur. This involves developing relationships with both vendors and buyers, and establishing a forum for microentrepreneurs in which they can discuss the common challenges they face. For example, the NGO Save the Children supports economic opportunities through Microenterprise Networks, which provide support to microentrepreneurs working in a specific industry or service. NGOs can also help create bridges between microentrepreneurs and receptive markets, including those located outside of their local community. This can include improving competitiveness by helping microentrepreneurs meet quality standards, providing communications links between the enterprise and the market, increasing output capacity, and assisting with legal issues such as licenses and permits.

Value-Added Technology Introduction

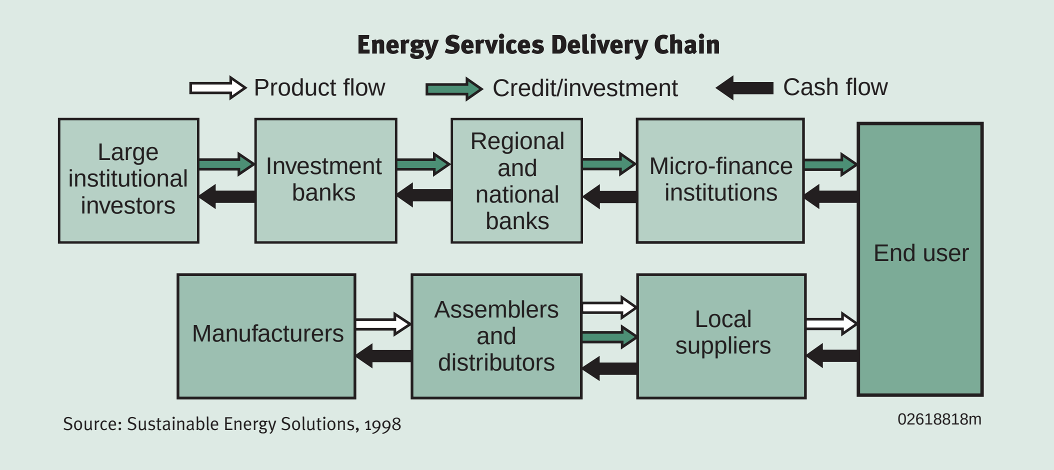
Helping microenterprises to adopt new technologies can add value by increasing productivity and expanding product offerings. In order for these new technologies to be successfully adopted, however, training is often needed. Appropriate Technology International (ATI) is an NGO that uses a problem-solving approach based on the "value chain"—the steps of production, processing, and marketing along which value is added. By providing access to credit and expert advice regarding technologies and connections to new markets, ATI-led value-chain programs help small producers.

Gender Equalization

It is estimated that between 30% and 60% percent of all microenterprises in Latin America and the Caribbean are owned and operated by women.[10] Other regions also have high proportions of women-led microenterprises. Microenterprise development organizations that assist women with income-producing activities provide valuable skills and training that often are not available to women from other sources. In addition, they help women achieve financial self-sufficiency.

Electricity

Electricity, a high-value form of energy, can be essential in facilitating improvements that lead to profitability and growth. Many business activities simply are not possible without electricity. The supply of electricity, however, has usually fallen under the jurisdiction of national or state governments. Because NGOs have not usually had much control over the availability



Source: Sustainable Energy Solutions, 1998

Figure 2.3. A delivery chain analysis is useful for illustrating the role MFIs can play in energy services delivery. The proximity of the MFI to the customer makes it an invaluable link in the chain.

of electricity, the provision of electricity to microenterprises often does not figure prominently as a targeted supporting service offered by microenterprise development organizations. However, the initial efforts of the Grameen Bank and BRAC (formerly, Bangladesh Rural Advancement Committee) in Bangladesh, the ACCION International affiliate-Genesis in Guatemala, and Sarvodaya in Sri Lanka, for example, indicate that the provision of electricity may be an area in which microenterprise development organizations will provide a valuable future service to microentrepreneurs.

Who Provides Microfinance?

The providers of microfinance are as varied as the borrowers they serve. They range from NGOs that have incorporated a lending program into an integrated rural development program to regulated financial institutions (microfinance banks) that focus solely on lending. Between the microfinance banks and the formal banking sector lie several levels of mini- or small-credit providers that may incorporate some of the microfinance mechanisms into their program.

The specialized microfinance bank approach benefits from the ability to offer financial services in a businesslike manner, maintaining a professional relationship with borrowers. Isolating business practices from subsidized or charitable services keeps the relationships clear to both the bank and the customer. Some microfinance practitioners, however, feel that pure banking is inadequate to address the manifold needs of the rural poor. They argue that microfinance alone does not provide the necessary ingredients to help people emerge from poverty. From this perspective, many multifaceted programs have evolved that offer microfinance with other rural development services.

The lively exchange of information in the microenterprise development field allows successful models to be disseminated. Each institution, however, necessarily develops in one way or another its own unique program and gains experience unique to the conditions within which its programs operate. The following are four examples of well-known organizations involved in microenterprise development that have a microfinance component in the program.

ACCION International and Affiliates

ACCION International creates and supports a network of financially self-sustaining institutions that specialize in providing financial services to the poor on a massive scale. All of the network affiliates provide small, short-term loans at commercial rates for working capital, and most also provide business training to microentrepreneurs in low-income communities. A few of the affiliates are offering additional financial services, such as savings and financing for fixed assets. The ACCION network has pioneered the solidarity group-lending program and also offers loans to individual entrepreneurs. ACCION is also pioneering efforts to link the world's capital markets to enterprises of the poor. ACCION works with 24 affiliates in 13 Latin American countries. Overseas NGO affiliates include Banco Solidario SA (BancoSol) in Bolivia and FUNTEC / Genesis in Guatemala.[11]

CARE

CARE is an example of an international development NGO that offers a wide range of services to meet the needs of rural populations. CARE, which celebrated its fiftieth anniversary in 1995, was founded when 22 organizations formed a cooperative to rush life-saving CARE packages to victims of World War II. Since then, CARE has been an early leader in long-term development projects that enable impoverished people to become self-sufficient. CARE programs offer technical assistance, disaster relief, training, food, other material resources, and management. CARE has a Small Economic Activity Development program that is aimed at both individual women and at local lending organizations. CARE works with individuals to expand their business skills and self-confidence. At the same time, CARE works in partnership with both formal and informal lending institutions to ensure that financial services are available to support microenterprises in the future.[12]

FINCA (Foundation for International Community Assistance)

FINCA's mission is to support the economic and human transformation of families trapped in severe poverty. This transformation is accomplished through the creation of "village banks," which are peer groups of 20-50 members—predominantly women—who receive three critical services: 1) working capital loans to finance self-employment activities, 2) a safe place to accumulate savings, and 3) mutual support for personal growth. FINCA's loans are backed by "moral capital," i.e., the collective guarantee of all members for each other. Village bank members make and sell crafts, foods, ceramics, clothing, and many other market goods. Some women set up shops, raise chickens, fruits or vegetables, and others choose a collective project.[13]

Grameen Bank

The Grameen Bank in Bangladesh has provided microlending services to poor women since 1976. The bank membership is overwhelmingly female (94%). Grameen Bank targets the poorest of the poor, requiring new members to be functionally landless. Members are required to learn to sign their name and to memorize 16 "commandments," which contain guidelines for health, education, and prosperity. Loans are accompanied by mandatory contributions to savings and emergency funds. Grameen Bank is an example of a "minimalist" MFI, as it primarily offers banking services. Other development activities, such as education and health, are promoted through independently operated and financed NGOs, which belong to the Grameen family. Grameen Bank currently has more than 2.4 million members in Bangladesh served by more than 6,000 branch offices. Its repayment rates consistently range between 96% and 98%.

CHAPTER 3.
RENEWABLE ENERGY SYSTEM COMPONENTS

This chapter gives an overview of the main components typically used in renewable energy systems, including how they work, proper use, cost, lifetime, and limitations.

System Overview

A stand-alone energy system comprises components that produce, store, and deliver electricity to the loads. Figure 2.1 shows a schematic of a hybrid system with more than one source of energy. Not all systems have all the components shown, but most will have components from each of four categories:

- Energy generation—To convert mechanical or light energy into electricity.
- Energy storage—To store energy and release it when it is needed. The most common energy storage device used in stand-alone energy systems is the battery.
- Energy conversion—To convert AC electricity to DC or vice versa.
- Balance of systems (BOS)—To connect the other components, monitor system performance, and protect the system.

Table 3.1.

Energy Generation	Storage	Conversion	Balance of System
PV Wind Micro-hydro Diesel/Gas Generators Biofuel	Batteries	Inverter Rectifier	Controls Meters Wires Fuses

02618819m

Photovoltaics

Photovoltaic (PV) modules convert sunlight directly into direct current (DC) electricity. PV modules, which usually have no moving parts, are highly reliable, are long-lived, and require little maintenance. PV modules can also be easily assembled into an array that can meet any size load. Despite its high capital cost, PV is often a cost-effective option, especially for small systems.

PV Module Construction

PV modules consist of individual cells wired together to produce a desired voltage and current. The cells are usually encapsulated in a transparent protective material and housed in an aluminum frame. PV modules last a long time, with warranties up to 20 years. PV manufacturers use a variety of technologies; these are generally classified as monocrystalline, polycrystalline, thin-film, or amorphous. Amorphous technologies are generally less efficient and may be less robust, but they are easier to manufacture and usually cheaper. For applications in which space and weight are not big concerns, initial or life-cycle cost and useable life may be the most important factors.

PV Module Performance Characterization

PV modules are rated in terms of peak watts (Wp) or peak kilowatts (kWp), a function of module size and efficiency. This rating scheme makes it easy to compare modules and prices, based on cost per rated Wp. The rating is an indication of the amount of power that the module will produce under standard reference conditions (1 kW / m^2; 20°C [68°F] module temperature)—roughly the intensity of sunlight at noon on a clear summer day. Thus, a module rated at 50 Wp will produce 50 W when the insolation on the module is 1 kW / m^2 and the temperature is average. Because power output is roughly proportional to insolation, this same module could be expected to produce 25 W when the insolation is 500 W / m^2.

Module energy production can be estimated by multiplying the module’s rated power by the site’s insolation on the module’s surface, typically 1400–2500 kilowatt-hours (kWh) / m^2 per year, or 4–7 kWh / m^2 / day. The resulting product is then derated by 10%–20% to account for losses caused by, for example, temperature effects (modules produce less energy at higher temperatures), battery inefficiencies, and wire losses.

PV Module Operation

The energy from PV modules can be used directly or indirectly for the target load(s). Most PV modules are designed to charge 12-V battery banks. Larger off-grid systems may use other DC voltages, commonly 24, 48, 120, or 240 V. For non-battery-charging applications, such as when the module is connected directly to a water pump, a maximum point power tracker can help improve efficiency by matching the electrical characteristics of the load and module.

PV modules are available in a wide variety of ratings up to 100 Wp, and modules rated as high as 300 Wp are manufactured. Individual PV modules can be connected to form arrays of any size. Modules may be connected in series to increase the array voltage, and they can be connected in parallel to increase the array current. This modularity makes it easy to start out with a small array and add additional modules later.

PV modules are mounted facing toward the sun on either fixed or tracking mounts. Because of their low cost and simplicity, fixed mounts set at an optimal angle are more common. They can be made of wood or metal, and can be purchased or fabricated almost anywhere. Tracking mounts (single- or dual-axis) can increase energy production, particularly at low latitudes, but these add cost and complexity.

SOLUZ, Inc. / 02618842

Figure 3.1. Multiple modules can be connected for larger energy needs.

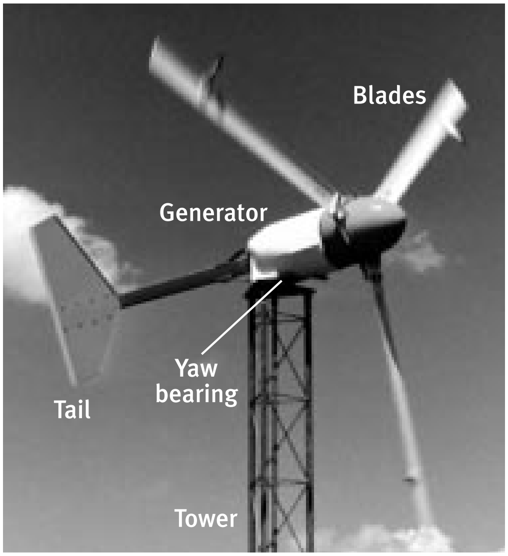
PV Module Capital and Operating Costs

The costs of a PV array are driven by the cost of the modules. Despite declining prices in the last two decades, PV modules remain expensive. Retail prices for modules in 1998 were generally at least $5,500 per kWp; for bulk purchases, prices can go below $4,000 per kWp. Warranties are typically for 10 to 20 years. Current modules can be expected to last in excess of 20 years. Costs for mounts, wiring, and installation are typically $1,000–$1,500 per kWp.

Despite its high initial cost, PV can be an attractive option, particularly for smaller-load situations, given its durability and modularity. PV modules themselves are virtually maintenance-free. Mostly, they need only to be kept clean, and the electrical connections inspected periodically for loose connections and corrosion.

Wind Turbine Generators

Wind turbines convert the energy of moving air into useful mechanical or electrical energy. Wind turbines need more maintenance than a PV array, but with moderate winds, 4.5 meters per second (m / s) or greater, they typically produce more energy than a similarly priced array of PV modules. Like PV modules, multiple wind turbines can be used together to produce more energy. Because wind turbine energy production tends to be highly variable, wind turbines are often best combined with PV modules or a generator to ensure energy production during times of low wind speeds. This section focuses on small wind turbines with ratings of 10 kW or less.



Bergey Windpower Co., Inc. / PIX02103

Figure 3.2. One of several kinds of wind turbines

Wind Turbine Components

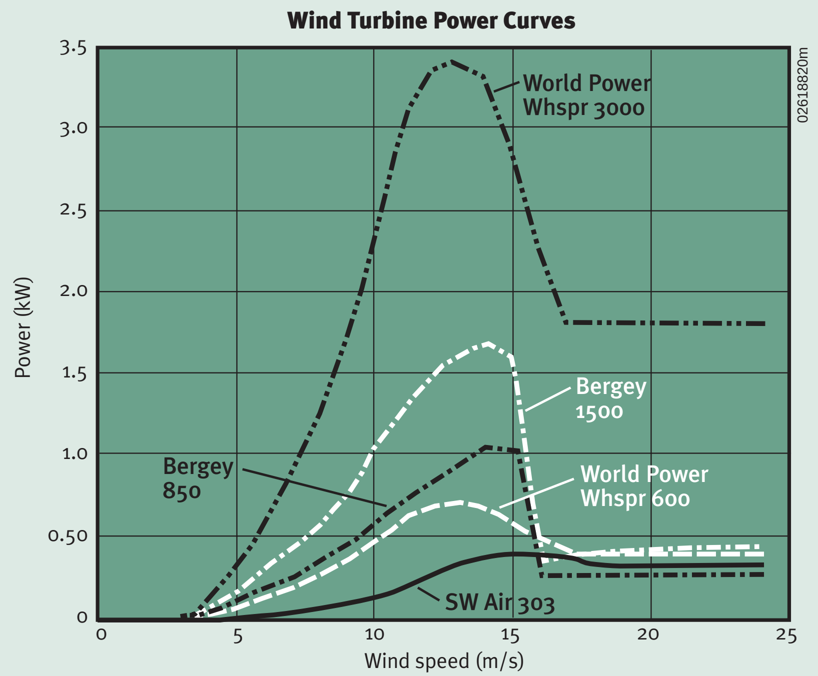
The components common to most wind turbines are shown in Figure 3.2. The blades capture the energy from the wind, transferring it via the shaft to the generator. In small wind turbines, the shaft usually drives the generator directly. Most small wind turbines use permanent magnet alternators as generators. These produce variable-frequency “wild” AC that the power electronics convert into DC electricity. The yaw bearing allows a wind turbine to rotate to accommodate the changes in wind direction. The tower supports the wind turbine and places it above any obstructions.

Wind Turbine Performance Characteristics

A wind turbine’s performance is characterized by its power curve, which relates wind turbine power output to the hub-height wind speed. Power curves for selected machines are shown in Figure 3.3. Turbines need a minimum wind speed—the "cut-in" speed—before they start producing power. For small turbines, the cut-in speed typically ranges from 3 to 4 m / s. After cut-in, wind turbine power increases rapidly with increasing wind speed until it starts leveling off as it approaches peak power. The energy production is dependent on the cube of the velocity. Thus, wind turbines produce much more power at higher wind speeds than at lower wind speeds, until the "cut-out" speed. Most small turbines produce peak power at about 12–15 m / s. Cut-out, usually at speeds of 14 to 18 m / s, protects the turbine from over-spinning in high winds. Most small turbines cut-out by passively tilting (furling) the nacelle and rotor out of the wind. After cut-out, wind turbine power output usually does not end, but remains at 30%–70% of rated power.

Wind turbines are rated by their power output at a specified wind speed, e.g., 10 kW at 12 m / s. Usually, this rating is at or near the wind turbine’s peak power output. The wind speed at which a turbine is rated is chosen arbitrarily by the manufacturer.

The nonlinear nature of the wind turbine power curve makes it more difficult to predict the long-term energy



02618820m

Source: Manufacturer's data

Figure 3.3. Selected wind turbine power curves

performance of a wind system than a PV system. Predicting long-term performance requires data on the wind speed distribution rather than just the average wind speed.

Wind Turbine Capital and Operating Costs

Wind turbine prices vary more than PV module prices. Similar-sized turbine installations can differ significantly in price, because of wide pricing variations among turbine manufacturers and widely varying tower costs based on design and height. Installed costs generally vary from $2,000 to $6,000 per rated kW. Unlike PV, wind turbines offer economies of scale, and larger wind turbines generally cost less per kW than smaller wind turbines.

Maintenance costs for wind turbines vary. Most small wind turbines require some preventive maintenance, mostly in the form of periodic inspections. Most maintenance costs will probably be for unscheduled repairs—lightning damage or corrosion, for example.

A wind turbine that will produce about 500 kWh / month of energy at a typical average wind speed of 6 m / s will typically cost $3,500–$5,000.

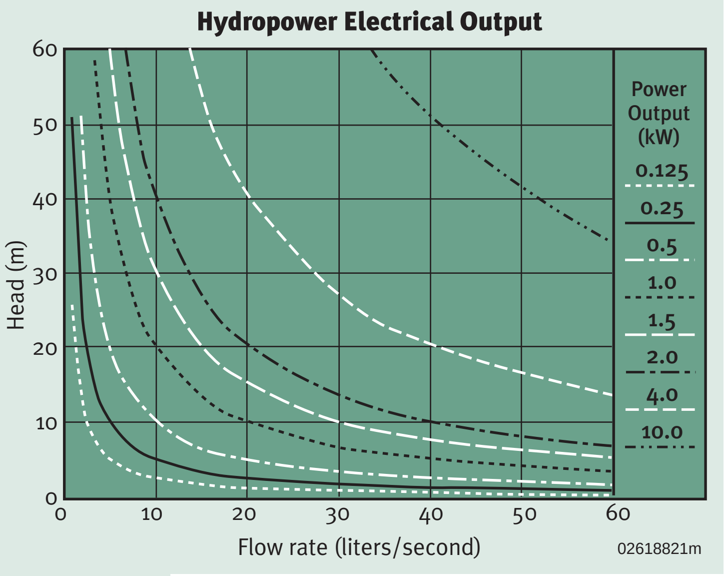


Figure 3.4. Estimated hydropower generator output as a function of head and flow rate

Micro-hydro

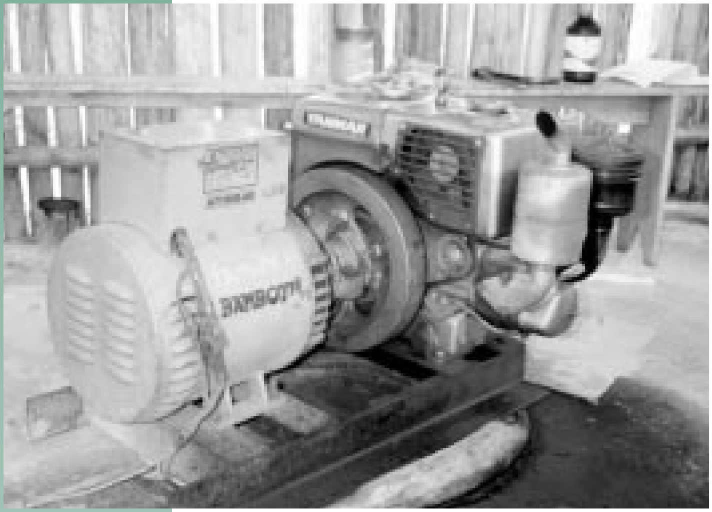
Micro-hydro installations convert the kinetic energy of moving or falling water into electricity. These installations may require more extensive civil works than other technologies; however, at appropriate sites, micro-hydro can be, on a life-cycle basis, a very low-cost option. The water resource of a micro-hydro installation may be subject to seasonal weather extremes such as drought or freezing. But unlike PV or wind turbines, a micro-hydro installation can produce power continuously. Because of this continuous power production, even a small installation will produce large amounts of energy.

Components

The components of a micro-hydro installation include the civil works, penstock, turbine, generator, and controls. The civil works, which consists of a water channel, diverts water from the stream or river to the penstock. The penstock conveys the water under pressure to the turbine. Piping used in the penstock must be large enough to avoid excessive friction losses. Different types of turbines are available, depending on the head (pressure) and flow rate at the site. Impulse turbines, such as the Pelton or Turgo, have one or more jets of water impinging on the turbine, which spins in the air. These types of turbines are most often used at medium- and high-head sites. Reaction turbines, such as the Francis, Kaplan, and axial models, are fully immersed in water. They are used more often at low-head sites. The turbine is connected to a generator that produces electricity. Both AC and DC generators are available. Governors and control equipment are used to ensure frequency control on AC systems and to dump excess electricity.

Performance and Cost

The power output of a micro-hydro system is a function of the product of the pressure (head) and flow rate of the water going through the turbine. Figure 3.4 shows estimates of generator output in relation to various head and flow rates. The selection of a site is usually a compromise between the head and flow rate available and the



Ken Olson, SEI / PIX06495

Figure 3.5. Generators run on many different fuels.

cost of the water channel and penstock. Because micro-hydro systems produce continuous power, even a small system will produce a large amount of energy. For example, a 125-W system will produce 3 kWh a day. The water resource of a micro-hydro installation may be subject to seasonal variations such as winter freezes, spring runoff, or drought. Where peak power demand is greater than what the installation can supply, a battery bank can be used to store energy during low-demand times for use in high-demand times.

Because of varying requirements for water channels and penstock, the cost of micro-hydro systems varies widely from location to location. In general, the cost for most systems is $1,000 to $4,000 per kW. Maintenance costs are about 3% of the capital cost per year. Much of the maintenance consists of regular inspections of the water channel and penstock to keep them free of debris. Micro-hydro installations can last very long, and maintained systems last in excess of 50 years.

Unlike PV and wind systems, micro-hydro installations are not modular. The available water resource and size of the civil works and penstock limit the power output of a given micro-hydro system. Increasing the capacity of the civil works is expensive. Thus, micro-hydro installations require that long-term demand be carefully considered.

Diesel, Gas, or Biofuel Generators

Generators consist of an engine driving an electric generator. Generators run on a variety of fuels, including diesel, gasoline, propane, and biofuel. They have the advantage of providing power on demand without the need for batteries. In comparison to wind turbines and PV modules, generators have lower capital costs but higher operating costs. Diesel generators—the most common type—are available in sizes ranging from under 2.5 kW to more than 1 megawatt. Gasoline generators, though less common than diesels, cost less and are available in very small sizes—as low as a few hundred watts. They are, however, short-lived, expensive to maintain, and inefficient. Generators should usually be run at a high load (> 60%); low-load operation decreases the fuel efficiency and may increase the need for maintenance.

Batteries

Batteries are electrochemical devices that store energy in chemical form. In energy systems they can store excess energy for later use to improve system availability and efficiency. By far the most common type of battery is the lead-acid type. A distant second is the nickel-cadmium type. The remainder of this section discusses the lead-acid battery.

April Allderdice / 02618832

Figure 3.6. A Shakti technician gives training on battery maintenance.

Battery Selection Considerations

Deep-Cycle versus Shallow-Cycle

Some batteries, known as deep-cycle batteries, can be cycled more deeply—have more energy taken out before being recharged—without suffering as much damage as some others. For remote power applications, deep-cycle batteries are generally recommended. They are designed to be discharged down to a 20%–50% state of charge. Shallow-cycle batteries, such as car batteries, are often used in small PV systems because of their broad availability and low initial cost. But they can have considerably shorter lives and may not weather deep discharges well.

Flooded versus Valve-Regulated

The plates of flooded batteries are immersed in a liquid electrolyte and need periodic rewatering. In valve-regulated batteries, the electrolyte is in the form of a paste or contained within a glass mat. Valve-regulated batteries do not need rewatering. Flooded batteries generally have lower capital costs than valve-regulated batteries and can withstand more extreme operating conditions. With proper maintenance, they tend to last longer. On the other hand, where maintenance is difficult, valve-regulated batteries may be the better choice.

Lifetime

The life of a battery generally depends greatly on its use. Batteries tend to last longer when cycled less deeply. Even if it is never or only occasionally used, however, a battery will fail at the end of its float life, typically three to eight years. High ambient temperatures can severely shorten a battery's float life—every 10°C (18°F) increase in average ambient temperature will approximately halve the battery float life.

Sizes

The storage capacity of a battery is commonly given in amp-hours at a given rate of discharge. When multiplied by the battery's nominal voltage (usually 2, 6, or 12 V), this gives the storage capacity of the battery in kWh. This storage capacity is not a fixed quantity, but rather depends somewhat on the rate at which the battery is discharged. A battery will provide more energy if it is discharged slowly than if it is discharged rapidly. In order to facilitate uniform comparison, most battery manufacturers give the storage capacity for a given discharge time, usually 20 or 100 hours. Individual batteries used in renewable energy systems are available in capacities ranging from 50 amp-hours at 12 V to thousands of amp hours at 2 V (0.5 kWh to several kWh).

Cost

Because of variations in cycle and float life, comparisons of the cost-effectiveness of different batteries are not obvious. In general, however, costs are on the order of $70–$100 per kWh of storage for batteries with lifetimes of 250 to 500 cycles and float lives in the range of three to eight years. There may be additional one-time costs for a shed, racks, and connection wiring.

April Allderdice / 02618852

Figure 3.7. A worker assembles inverters and controllers at Lotus Energy plant in Nepal.

Inverters

Inverters convert DC—the output from PV modules, batteries, and most small wind turbines, for example—to AC power. Many common electrical applications and devices require AC power, which generally takes the form of a sine wave. Inverter AC outputs can be crude, square wave, a modified sine wave, or pure sine wave. Many devices won't operate properly on the square-wave inverters. The modified sine-wave inverters, which produce an improved "staircase" square wave closely approximating a sine wave, can be used for most AC electronic devices and motors. Manufacturing a pure sine-wave inverter is very expensive; modified square-wave inverters are, therefore, the most common choice.

Inverter size ratings usually reflect their maximum power output when operated for an extended period of time. Most inverters specify a capability to handle significantly more power briefly (surge capacity) to meet the current needed to start a motor, for example. The cost of a high-quality modified sine-wave inverter is roughly $500 to $1,000 per kW. At the low end, small 100- to 200-W inverters are available for around $100 to handle many simple applications. A wide number of larger sizes are available above that, although inverters with a capacity above about 5 kW can be more expensive per kW of capacity.

Balance of Systems

Controllers and meters act as the brains and nervous system of an RE or hybrid system. In simple systems, controllers help the user protect the battery by automatically regulating against both battery overcharge and overdischarge. Metering allows the user to assess system performance and to stay within operating guidelines. In large, complex systems, various controlling and metering functions can be spread out over several different components. Because there have been problems with controllers involving reliability and damage from lightning, good RE system designs pay close attention to controller design and lightning protection.

Controller Purposes and Functions

Common controller functions include the following:

- System protection: A controller can include the fuses or circuit breakers needed in a system to protect against short circuits.
- Charge regulation: A controller with a proper battery charge algorithm or high-voltage disconnect protects the battery against overcharging.
- Low-voltage disconnect: A low-voltage disconnect can protect the battery against overdischarging.
- System monitoring: Monitoring the system currents and voltages lets the user check that the components and system are operating properly.
- Component control: The controller can be programmed to turn components on and off as needed without user intervention. For systems with excess energy, a dump load—often one or more big resistors—can help dissipate electricity by converting it to heat.

Balance of System

The BOS also includes items such as wiring and switches and can include conduits and fuses or breakers.

DC Source Center Use

Several manufacturers now offer DC source centers. These combine much of the system wiring, fusing, and controllers into one tidy, easy-to-install package. The use of source centers increases system costs somewhat, but offers easier installation, less complex wiring, and easier system monitoring and control. A source center should be especially considered for systems in remote sites that lack easy access to technical assistance. The initial investment pays off in reduced service costs over the long term.

CHAPTER 4. SYSTEM SELECTION AND ECONOMICS

Introduction

The first section of this chapter describes life-cycle cost analysis and explains how and why it should be used when analyzing the economics of various options. The second part of this chapter discusses the factors influencing system design, load, available resource, component costs, and desired level of service per these options. Included are charts that show how typical system costs vary as a function of load and resource.

Life-Cycle Cost Analysis

Why and When to Use Life-Cycle Cost Analysis

RE options tend to have high initial costs and low operating costs. Generators, in contrast, have low initial costs but high operating costs. Choosing options based solely on initial cost may lead to higher overall costs over the life of the system.

Because the actual cost of an energy supply system for a business includes both its initial investment cost (depreciated over its life) plus its future operating costs for fuel and maintenance, a cost analysis must factor in complete costs over the life of the project. Therefore, life-cycle cost analysis should be used to compare energy system options. System options will have different combinations of initial and future costs; the LCC analysis can help in making consistent comparisons between the options. This type of analysis also takes into account initial and future costs, while recognizing the "time value of money" (i.e., a dollar in the future is worth less than a dollar today).

LCC analysis is generally the preferred method for evaluating the economics of different projects with differing initial and future costs. LCC involves a discounted cash-flow calculation whereby the total cost of an option (its net present cost) is determined by summing the discounted annual cash flows of that project over its lifetime. Future cash flows (perhaps for fuel) are "discounted" by a "discount rate." The rate at which the future expense cash flows are discounted is usually set at a cost of capital (COC), which for a microenterprise can be very high. Although soft-funded projects may have discount rates of 10% and U.S. corporations may use a COC of 25% when comparing investment options, based on their perceived opportunity cost, a rural microenterprise may need to use a discount rate as high as 50%. An economics reference book would be useful in providing more details on how to perform a discounted cash flow LCC analysis.

Although LCC can be used for any project, it is particularly appropriate for RE projects of 5 to 10 years or more in which the fuel and repair costs of generators, for example, become considerable. The LCC analysis is less reliable in cases in which the future of a microenterprise is predictable only for a few months or a couple of years, unless the resale value of the RE system can be assured. An LCC analysis is sensitive to the inputs; thus, sensitivity analysis should be done over a plausible range of input values. LCC implicitly assumes that the options being compared provide comparable levels of service. If the options provide differing levels of service, this difference should be accounted for in the option selection process.

Some RE projects incur higher-than-expected operating costs caused by improper installation and lack of operator training. Sufficient attention should be paid to ensure that the RE system installers in the project are properly trained and that the end users and / or operators are properly educated at the time of installation. The cost of servicing single systems in dispersed communities can also contribute to high operating costs. The cost of servicing RE systems can be greatly reduced if the systems can be maintained by locally based personnel who have sufficient RE business activity to ensure an efficient maintenance service.

Fuel Subsidies

In many countries, fuel costs are artificially low because of government subsidies. To fully capture the potential operating cost savings offered by RE, economic analyses of any project for which the the government would pay for fuel should use the unsubsidized fuel cost. Although economic analysis of private systems should use the subsidized fuel cost, project developers should consider the probability and effects of the removal of fuel subsidies some time during the lifetime of the project.

Excess Energy

Less modular RE systems, such as microhydro, often produce excess energy, which can be used to generate additional income. Finding resourceful ways to use excess power improves the economic viability of the system and can be included in the LCC analysis.

Income Generation

An important part of the LCC analysis will be the capacity of the RE-generated power to generate income. Larger or more sophisticated systems may be worth the investment if they increase the income-earning potential of the beneficiaries sufficiently.

Design Considerations and Economics

This section describes the factors that affect system configuration and costs. The main considerations driving system selection are loads, resources, costs (component, fuel, and operating), and quality of service.

Energy/Power Consumption (Loads)

The electrical consumption patterns of microenterprises are a primary factor influencing energy system design. The person selecting the renewable energy system needs to take into account maximum power consumption (the load measured in watts), energy consumption (a measure of the load hours used over a period of time or kWh / year), seasonal and daily energy consumption variations (a measure of load distribution), and quality of service needed.

The system is designed and components—the generator, the batteries, the wiring and power electronics—sized so that the system can both deliver the maximum power specification and meet the average energy consumption specification (kWh / month). Maximum power requirements drive the size of wiring and control equipment. Energy consumption and variations over time will drive the type and size of the energy-producing components and will also influence the size of the battery storage.

The RE technology selected may depend on load variations over each day and during the year. Summer and daytime loads, for example, can tend to favor PV because of the clear match between when the solar energy resource is available and the time energy is needed. Heavy winter loads may be more suited for generators; if winter is the windy season, however, then wind turbines could be appropriate. If the wind and solar resource are seasonally complementary (i.e., the wind resource is good during the low-insolation season), then a wind-PV hybrid system may be most appropriate.

Common microenterprise loads include the following:

- **Lights, radios, television sets, and cell phones**—These loads may be operated using small PV systems (20-200 W) and wind-electric systems (300-500 W). Most of these loads can be operated using DC. For AC loads, such as those for color TVs and VCRs, a small inverter can be included. Slightly larger PV systems (250-1,000 W) and wind electric systems (1,000-3,000 W) are suitable for slightly greater needs, such as light-use motors for sewing machines, refrigerators, hand power tools and fans, or for small amounts of heat (such as that needed for soldering irons).

- **Power tools, grain mills, or other large motors for workshops and light industries**—These loads will typically need larger power systems.

April Allderdice, NREL / PIX07151

Figure 4.1. Bangladeshi electrical repair shop uses solar-powered light and soldering iron to increase productivity.

SELCO / PIX08143

Figure 4.2. A Nepali woman weaving under a solar light in her home

Larger hybrid systems that contain some combination of solar PV, wind, gasoline or diesel generator, battery, and inverter can meet these loads as well as the loads described in the previous paragraph. Where the resource is available, micro-hydroelectric technologies can also meet these loads, possibly without requiring fuel or batteries.

- **Water pumping, ice-making, and battery charging**—These loads occasionally can be operated by simple systems that do not require energy storage. Loads that do not need to be run at a particular time, but can be operated when the resource is available, may not need a battery, resulting in significant cost savings. When these "deferrable" loads are operated with other loads, they can be run whenever extra energy is available, which also generates cost savings by allowing available energy to be used more efficiently.

- **Process heat, cooking, and drying for food preservation**—Thermal loads are generally better met with a thermal technology than an electrical technology. Although electricity can be used to create heat, it is usually much more expensive than alternative technologies. Renewable thermal technologies include solar water heaters, solar cookers, and solar dryers—all of which use the sun's heat rather than its light. Biogas can also be burned for heat. Most of the technical discussion in this guidebook focuses on electrical energy issues; for more information about thermal technologies, please see the bibliography.

Large enterprises, energy entrepreneurs, and microenterprise zones may supply several different types of loads with the same system. Where many loads occur at once, demand-side management—the conscious timing of the operation of each load, together with a special attention to efficiency in the loads—can result in more efficient energy use and significant savings in initial investments and operating costs.

Resources

The availability of wind and solar resources greatly influences both the configuration and the cost of a renewable energy system. A good wind resource will favor the use of wind turbines, whereas a good solar resource will favor the use of PV. Another consideration is the variability of the resource, both daily and seasonally. The time period of importance depends on the system configuration. For a stand-alone RE system, the designer will be more interested in the monthly average resource and should size the PV array or wind turbines based on the lowest-resource month. For a system with generator backup, sizing the RE components using average annual resources may be more appropriate.

Virtually all locations experience seasonal variations in solar insolation and wind speed distribution. These variations mean that power production from PV arrays and wind turbines is not consistent. RE system designers must make up for this natural variation when they design the system. Seasonal variations in insolation are driven by the changing length of the day as the season progresses and by seasonal climate patterns (e.g., rainy seasons). This type of variation can be partially overcome by tilting the PV modules at an optimal angle. The wind resource is also usually seasonally variable. Even areas with relatively good wind resource usually have a one- or two-month period of low average wind speeds. It is important to determine if the microenterprise will be negatively affected by a low season for wind resource. If the business using the RE system is also seasonal and the business and wind seasons happen to coincide, the enterprise may benefit from a more economical system. Where a low wind resource season would negatively affect the microenterprise operation, a PV system or a hybrid system using wind-PV, wind-diesel or wind / PV-diesel may be preferable.

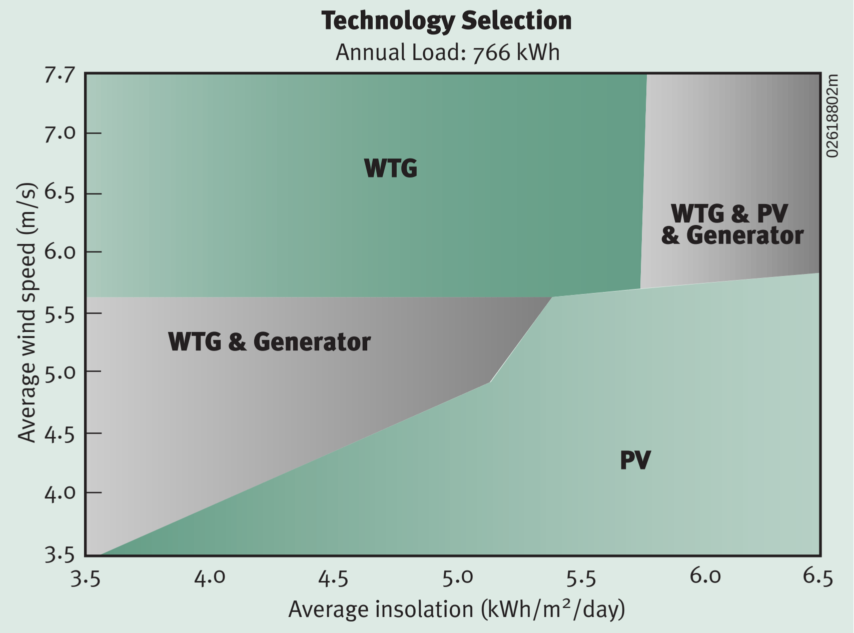


Figure 4.3. This graph shows how the least-cost configuration for a microenterprise zone can vary as a function of wind speed and solar insolation. These results are meant to show general trends only. (WTG = wind turbine generator)

Although long-term averages drive the sizing of the wind turbine and PV capacity, short-term (on the order of days) fluctuations in wind and sunlight will influence the amount of storage required. The longer the lulls in wind and sun resources, the larger the amount of storage needed. These lulls drive up the cost of 100% RE systems. Systems with generator backup, however, do not need batteries sized to meet the longest anticipated lull in the resource.

The effect of resource on technology selection is illustrated in Figure 4.3. Figure 4.3 shows, for an average load of 700 Wh per day (766 kWh per year), how the configuration of the lowest-cost system varies depending on the local solar and wind resources.

Cost Comparison Chart

Technology			Energy Demand (kWh/month)		
		COC	25	200	800
PV at 5 kWh/day	Initial Investment		$3,200	$19,800	$80,400
	Annual Operating Costs		–	–	–
	Net Present Value	10%	**2,600**	15,300	61,800
		25%	**3,000**	18,600	74,300
	Annualized Capital Costs	10%	400	2,500	10,100
		25%	2,500	5,200	2,500
Diesel Battery Hybrid at $0.28/liter	Initial Investment		$400	$4,200	$4,500
	Annual Operating Costs		700	500	2,200
	Net Present Value	10%	5,800	9,300	30,700
		25%	3,600	**8,100**	**19,900**
	Annualized Capital Costs	10%	900	1,500	5,000
		25%	2,500	2,000	2,500
Wind Hybrid at 6 m/s	Initial Investment		$3,800	$8,800	$21,500
	Annual Operating Costs		100	200	500
	Net Present Value	10%	3,800	**8,500**	**20,200**
		25%	4,000	9,100	21,900
	Annualized Capital Costs	10%	600	1,400	3,300
		25%	2,500	2,500	6,100

Assumptions

1) Project life = 10 years
2) PV, inverter, and battery maintenance costs depend on local labor costs, present a marginal increase in cost and are not included here.
3) PV system (modules and mounting structure): Linear depreciation over 20 year life
4) Diesel system: Linear depreciation over 2500 hour life
5) Wind system (turbine and tower): Linear depreciation over 12 or 16 year life (depending on turbine size)
this color represents the system of choice for each load size and discount rate

Notes

1) "COC" is the cost of capital, or real discount rate.
2) PV costs will vary linearly with resource.
3) Diesel costs will vary linearly with cost of fuel.
4) Wind costs will vary exponentially with resource.
5) The system configuration is held constant in the COC comparisons. In the case of the 800 kWh load, the optimal system at a 25% COC, a hybrid system using less wind, and more diesel, is not represented.
6) PV-gas hybrids are not presented here. For the 25 kWh system, a PV-gas generator hybrid is optimal.

02618811m

Figure 4.4. This cost comparison chart shows how the initial and operating costs for a sample renewable energy system will vary depending on the technology, load site, and financing terms. The system with the lowest net present value of life-cycle costs is highlighted. Incoming cash flows from user payments are not considered here. In this case for small loads, solar PV is the most economical option, since economies of scale for centralized technologies are not yet achieved. As the load size increases, a wind or diesel system becomes more economical than PV. If the cost of capital is 25%/year, diesel battery hybrid is most economical because of its low initial costs compared to wind. If the cost of capital is only 10%/year, a wind hybrid system will make sense, because its low operating costs give it a long-term advantage over diesel.

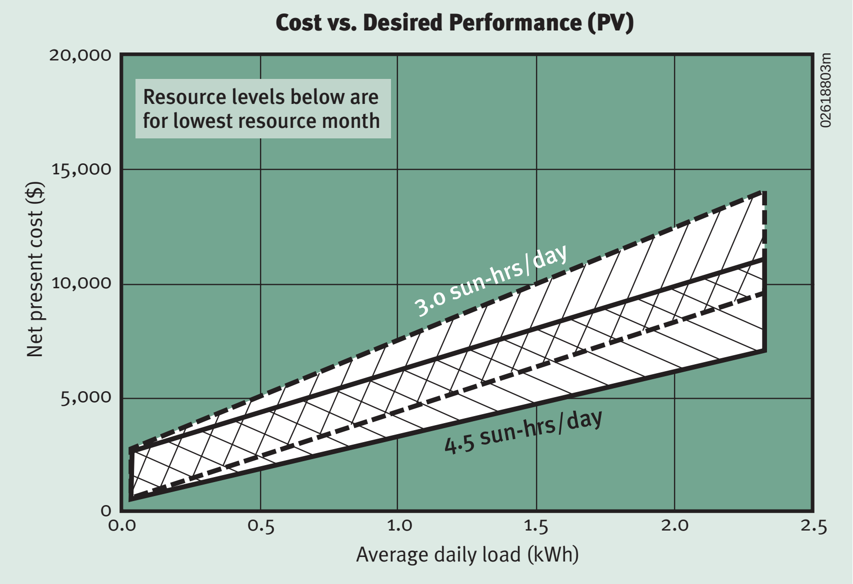
Costs

Figure 4.4 shows how the initial and operating costs will vary depending on the technology chosen and financing terms.

Figure 4.5 shows the typical range of costs for PV and WTG systems over a range of loads. Each graph shows two bands that reflect costs given two levels of resource availability. Because these are 100% RE systems, the resource level is not the annual average, but rather the average for the "worst" month. A couple of examples will clarify the use of the graphs. Figure 4.5a shows that a PV system capable of handling an average daily load of 0.5 kWh, in a locale with worst-month insolation (3.0 sun-hours / day), is expected to have a 25-year net present cost of between $2,500 and $5,000. Figure 4.5b shows that a WTG system that meets an average daily load of 1.0 kWh costs between $4,000 and $8,000 in a location with a worst-month average wind speed of 5.0 m / s.

Quality of Service

The last important load-related consideration is quality of service. This refers to the system's capability to meet the load given the variability of the solar insolation and wind resources. There may be times when little of the natural energy resource is available, so the RE system may not deliver sufficient power. For an RE system that does not have a diesel backup, the costs may be excessive if the system needs to provide power without any "downtime." If system components, especially the battery bank, are sized for the worst possible case, the system



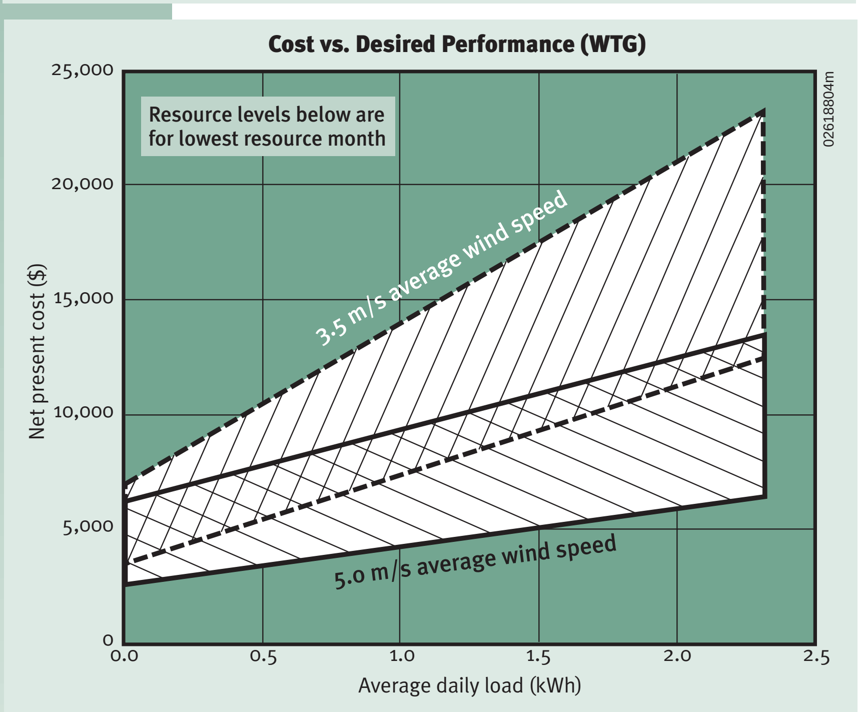


Figure 4.5. These graphs show the typical cost range of the technology (photovoltaics or wind turbines) for a system as a function of the average daily load. The resource availability listed (for both wind and sun) is the month with the lowest resource availability.

will be oversized at all other times. If the microenterprise can operate with little reduction in profits even if the power system has some down time—or, put another way, "with proper load management"—economy-seeking microentrepreneurs can save money on the capital costs of a system without affecting income-generating potential.

Generator Considerations

For larger loads (above ~1 kWh / day), a big decision is whether or not to use a generator. Ultimately, this decision will depend on an analysis of the site in question. The principal advantage of generators is their ability to provide power on demand, which can help avoid oversizing the RE generators and batteries. The disadvantage of generators is their high operating cost because of fuel and maintenance. Providing fuel and maintenance to remote sites is often problematic. Figure 4.6 shows the 25-year net present cost of a 2.5-kWh diesel generator as a function of average daily load and average daily run time. The figure shows how the number of operating hours drives the cost of using a generator. If the number of operating hours is low, generators can be cost competitive sources of energy. As operating hours increase, costs escalate. If the loads are lights and water pumps that are on only a few hours per day, then an all-diesel system may be cost competitive.

If the generator must be run more than a few hours per day, another solution is needed. One possible solution is to use a generator-battery system. When the generator runs, it

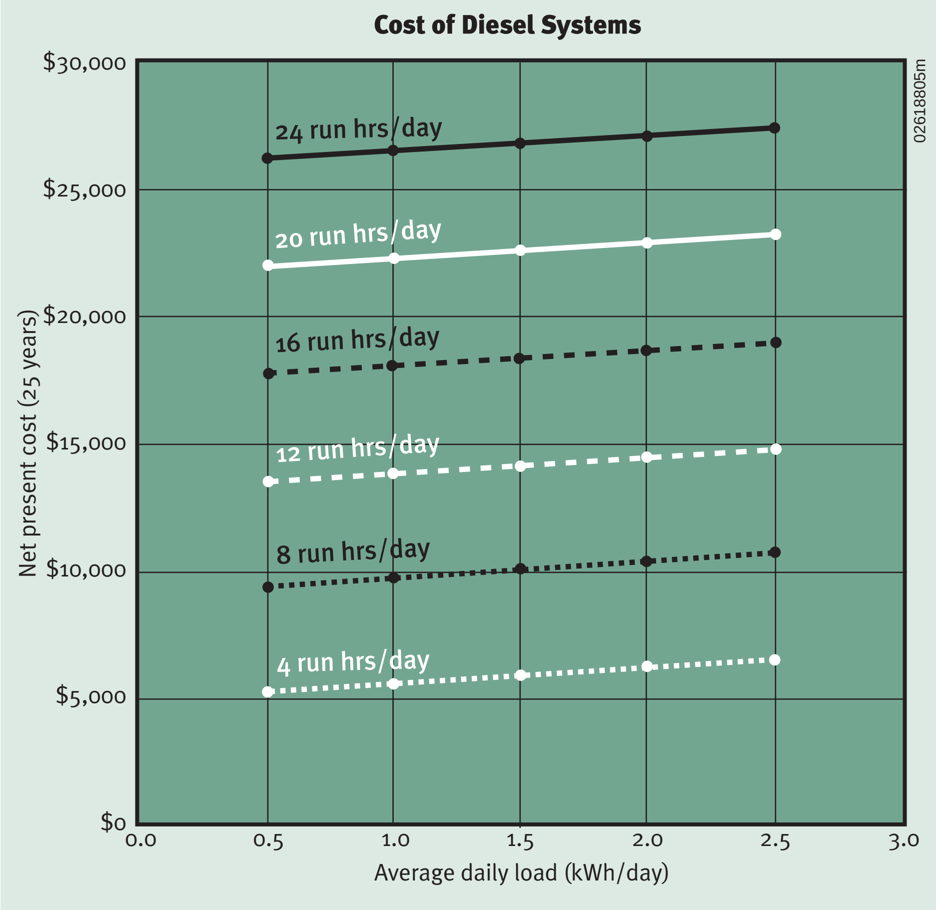


Figure 4.6. This graph shows the 25-year net present cost of using a diesel generator. The two variables are average daily load (kWh/day) and daily run hours. Note that the costs vary only slightly with load but escalate rapidly with increasing run hours.

charges a battery bank that then is used most of the time. The savings from reductions in generator run time can vastly outweigh the conversion losses caused by cycling energy through the battery and the initial cost of the batteries and inverter.

The other solution is to combine the generator with PV modules, wind turbines or both. The RE components minimize the generator run time, keeping generator operating costs to a minimum. The generator also precludes the need to oversize the RE components, thus reducing capital costs.

CHAPTER 5.
INSTITUTIONAL APPROACH NO. 1: PROVIDING END-USER CREDIT FOR INDIVIDUAL RENEWABLE ENERGY SYSTEMS

Introduction to Institutional Approaches

Chapters 5–7 classify the many institutional arrangements that work with microfinance practices or entities to enable microentrepreneurs to access renewable energy resources. The first approach—which is described in Chapter 5—addresses decentralized systems for individual microentrepreneurs. In other words, a separate RE system is used for each business, residence or productive application. These include systems usually referred to as a solar home system (SHS) or wind home system, names that inadequately describe the breadth of commercial and cottage-industrial applications enabled by small RE systems. This section also discusses both credit and fee-for-service approaches for financing small RE systems. Although some microenterprise organizations have chosen to carry out both the financial and technological functions in their energy provision program, others have been able to concentrate on their area of expertise by forming strategic alliances with RE suppliers who carry out the technological functions. This section provides examples of situations in which microfinancing is used for end-user financing of individual systems.

The second approach—described in Chapter 6—characterizes ways of promoting productive applications of electricity through community-scale systems, in which renewables are used to power an isolated minigrid or centralized microenterprise zone (MEZ). Microfinance institutions can either develop the

Table 5.1. Comparison of Three Institutional Approaches

Institutional Approach	Role of Microfinance	Role of Microenterprise Support	Role of Upstream Finance
End-User Finance	• Fixed-asset credit for RE system • Fixed-asset or working capital for productive uses • Finance for a package that includes an energy system, tools, and working capital	• Target income generation • Packaging generators and applications	• Capitalize revolving credit fund • Provide working capital for supplier-run credit program
Community-Based System	Fixed-asset or working capital for productive use	• Business incubator services • Promoting productive uses	Fixed asset lending for community energy system
Energy Entrepreneur	• Working capital for energy entrepreneur • Fixed-asset lending for RE system • Productive uses lending for community members	Evaluate the covenant between the community and the entrepreneur	Capitalize a revolving credit fund or bank program

02618815m

Table 5.2. Highlights of Institutional Approach No. 1

End-User Finance Approach	Variation	Energy system ownership	Participating Institutions	Risk
Third Party	Credit for sales	End user	Financer	Distributed between two organizations
			Supplier	
All-in-One	Credit for sales	End user	Energy service provider	Energy service provider
	ESCO	ESCO		

02618816m

community power system themselves, or they can work with a local electric cooperative, energy services company (ESCO), or NGO to bring electricity to their client entrepreneurs. In either case, MFIs and microenterprise support organizations can provide credit, training, and other services to enable microentrepreneurs to take advantage of available electricity.

In the third case—described in Chapter 7—the microfinance is extended to an "energy entrepreneur," who creates a business in which electricity is the main product. This arrangement has a two-tiered impact on the community. Not only does the energy entrepreneur create a sustainable livelihood, but the local business community also may be able to improve its microenterprises through the benefit of electricity access. These entrepreneurs include decentralized-system retailers, battery-charging stations, and mini-utilities.

More than one approach can be applied in a given community. For example, an energy entrepreneur may receive working capital for his / her small RE business, and his / her customers may use credit to obtain the tools or appliances that take advantage of the electricity.

Introduction to End-User Financing

MFIs have experience providing working capital and, in some cases, fixed-asset credit for income-generating applications. In areas where electricity is available, MFIs have financed tools or machines that depend on electricity to function. With the availability of cost-effective individual RE systems, it is a natural evolution for MFIs in unelectrified areas to finance income-generating applications packaged with the energy source they need to run. However, many MFIs are not familiar with energy technologies, and thus are hesitant to finance them. Moreover, they may not be familiar with the financing issues that are specific to energy technologies. This section gives examples of institutions that have undertaken financing for rural energy systems.

Typically, only the wealthiest residents of rural villages can afford to pay for an individual RE system up front. Therefore, two main approaches to end-user financing have emerged. The first involves a strategic alliance between a renewable energy supplier and a financial intermediary. This is known as a third-party approach because three entities (including the customer) need to be involved in every sale. In many cases, one institution carries out both the financial and the technical tasks. This guidebook refers to this approach as "all-in-one." The PV industry and, to a lesser degree, the wind industry offer many examples of successful small-scale consumer financing. This section examines how the end-user credit approach can take advantage of microfinance strategies and strengths to ease the burden of up-front costs for the customer and to expand market opportunities for the supplier and credit provider.

The Need for End-User Financing

A small percentage of rural villagers can afford to pay for RE systems with cash, but credit or rental options can expand the market significantly. One PV project developer estimated that a fee-for-service option in Indonesia, for example, would expand the market from less than 30% for direct-dealer sales to at least 70%.[13] The pyramid in Figure 5.1, illustrating estimates by another PV developer for one Latin American market, suggests a tenfold increase over the cash market.

Is a Renewable Energy System an Income-Generating Item?

A discussion of the many microenterprises that can improve their viability through electrification is given in Chapter 1. For machine-driven applications, such as icemakers or mills, the return on investment may be straightforward. However, most end-user financing provides small RE systems that mainly offer lighting benefits (although some small motors and entertainment equipment can also be run [see Chapter 4]).

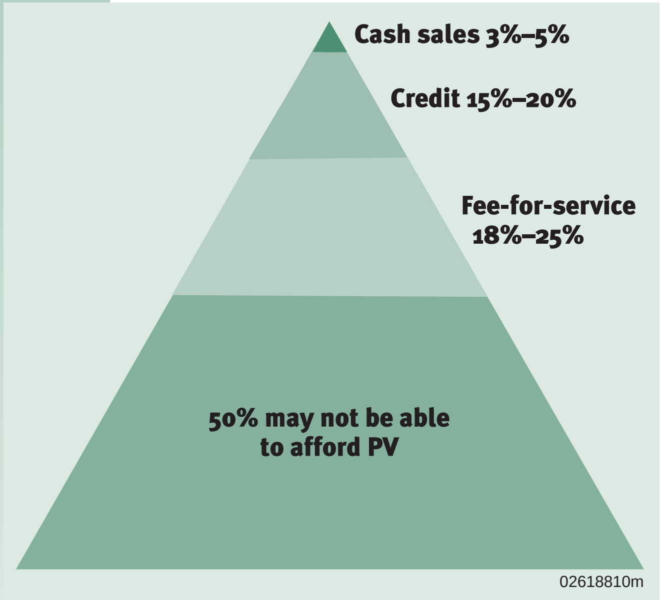


Figure 5.1. The pyramid shows one estimate of the proportion of end users that can afford PV under different purchasing options.

Renewable energy systems that provide domestic lighting may have long-term effects on the quality of life that are not as easy to quantify as those incorporated in businesses. An analog is an MFI-run housing program. Although the house is not considered an "enterprise," it has many positive financial implications for its residents. By protecting the family from rain and cold, it reduces the number of illnesses and medical costs. The space can be used for storing grains that can be sold later at a higher price. The sturdy walls reduce the cost of constant replacement or repair of tin modules or palm leaves. These constitute long-term economic benefits to the borrower.

Likewise, a lighting system provides light for study, which has long-term effects on the employment potential of the children. Electric lights are safer than kerosene lanterns, which can cause fires and produce smoke that is harmful to the eyes and lungs. And, finally, lighting systems may pave the way for small cottage industries to be carried out during evening hours.

In some cases, income generation is clearly linked to the availability of electricity. A sawmill in Bangladesh was able to increase its operating hours and income by 50% simply by extending its operating hours. For many businesses, however, the connection, while real, is less consistent. For example, a rural hardware store may expect to benefit from more customers if it stays open longer; however, it is difficult to anticipate how many more customers will come. Moreover, the increase may vary unpredictably. Thus, for the store, buying a small RE system may be more uncertain than investing the money in livestock or another traditional loan item that has an easily anticipated return.

Perhaps the most successful customers are those who are able to apply the system to both household and business use. In this situation, the RE system provides savings in traditional fuels, increased income from the business, and long-term returns in the form of improved health and education.

Can a Microfinance Organization Make Money by Financing Renewable Energy Systems?

The ability of a microfinance organization to make a profit financing renewable energy systems depends on its ability to transpose the successful microfinance innovations of the past to the new challenge of RE technologies. Such innovations include externalizing as many of the operating costs as possible, using inexpensive local labor, and generating economies of scale. Meanwhile, RE has several advantages that traditional loan items do not offer. RE can diversify a lending portfolio, bring down transaction costs, reduce risk through collateral, and allow access to governmental funds earmarked for environmental and rural electrification purposes.

Operating costs may mount in a renewable energy program if the MFI takes on too many of the responsibilities of technical supervision. Such costs can be externalized from the microfinance program by entering into a strategic alliance with one or more suppliers, or by creating an independent technical unit. Also, these costs can be reduced as local personnel are trained to take on program responsibilities, as in the Ramakrishna Mission Program described below. Choosing areas where economies of scale can be achieved is another way to reduce operating costs.

Loan portfolio diversification fortifies a credit program against sector-specific or clientele-specific disasters. Renewable energy systems facilitate diversification by providing services useful to a broad range of productive rural activities, from agriculture to commerce and industry. In addition, renewable energy systems may allow microfinance entities to target segments of the population not currently represented in their clientele base.

Ramakrishna Mission

The Ramakrishna Mission solar program in West Bengal, India, found a way to externalize a large portion of its training, sales, and maintenance costs. It certified hundreds of low-cost rural technicians who carry out the sales and maintenance tasks for a small fee, which they charge the end user.

Unlike many items for which microfinance loans are given (such as livestock), RE systems offer the additional advantage to the lending agency that the system itself can provide some measure of collateral. This case is particularly true with PV modules, which last a long time and lose value slowly after installation. In addition, the systems are more costly than traditional items. These larger transactions reduce the average transaction cost, which can increase profitability.

Finally, many countries view rural electrification and environmentally sound energy decisions as a policy priority. Microfinance agencies may find themselves in a position to channel government funds to programs that advance these goals. One example is Brazil’s low-interest line of credit for renewable energy. The Teotonio Vilela Foundation managed to access this line of credit for photovoltaic battery-charging station microentrepreneurs.

As microfinance program members increase their standard of living as well as their ability to borrow, they look for new items to invest in. Microfinance programs, such as the Grameen Bank in Bangladesh, have experienced this growth in their membership and have expanded their loan portfolio for items much more costly than their original program allowed. By meeting the demands of the more affluent customers, the microfinance organization also improves its own viability. Because these customers have established credit relationships with the organization, and because they have already been trained in banking procedures, the larger loans bring in higher interest payments with lower transaction costs. This increased income to the microfinance organization can be used to finance the expansion to new areas and training of new members at the poorest levels. In this way, upward diversification may advance the financial institution's goal of providing credit to the most needy.

Third-Party Financing

The third party-financing approach allows a microentrepreneur (the first party) to buy an RE system from a supplier (second party) through credit provided by an MFI (third party). This arrangement offers both advantages and disadvantages for the parties involved. An advantage of the third-party system for both the credit provider and the RE system supplier is that it allows each to fulfill specialized roles, focusing on the capabilities each has already developed. The MFI can process loans and collect payments as part of its normal credit activities, without entering into the technical and business aspects of RE system supply and maintenance. Moreover, the market will benefit from a more sophisticated credit program. The RE system supplier can focus on its normal technical and business issues without having to develop an additional capacity for rural credit administration.

Unlike sales based on a supplier's own credit, third-party financing is a cash sale as seen from the RE supplier's view, providing immediate cash flow and related profit margins. Access to credit from an MFI can expand an RE supplier's market significantly beyond straight cash sales in rural areas often underserved by traditional sources of financing. Moreover, customers of the MFI already have a credit history and an income-generating enterprise, making them good candidates to repay their loans.

Both for-profit and nonprofit organizations are involved in third-party financing for small renewable energy end users. Nonprofits range from large microfinance organizations involved in financing RE along with a wide variety of other products, to small NGOs dedicated to RE financing for qualified for-profit suppliers.

All-in-One

In the "all-in-one" approach to end-user credit, an entity from either a financing or system-supply background, expands its capabilities

Grameen Shakti

Grameen Bank, a microfinance pioneer, provides end-user financing for its members. The bank members purchase systems from Grameen Shakti, an independent (but related) RE supply company. Credit for renewable energy systems has fit easily into the bank's loan portfolio, which includes loans for such items as houses, cellular phones, and diesel generators.

A supplier who is not in a position to provide its own credit may find the growth of its business constrained by the financial or organizational capacity of the financing organization. In the case of Grameen Shakti, the Grameen Bank's membership was in general poorer than the initial target market for renewables. For that reason, Grameen Shakti was compelled to add its own credit scheme to that of the Grameen Bank. As of November 1999, Grameen Shakti had sold more than 1,000 systems.

ADESOL

The Dominican nonprofit ADESOL (the Association for the Development of Solar Energy) provides limited end-user financing through a network of independent PV microenterprises to give them experience with credit sales. The microenterprises prequalify customers and act as financial intermediaries for the transactions, including responsibility for collection; however, the loan remains an asset of ADESOL's development assistance revolving loan fund. Enersol, ADESOL's nonprofit, U.S.-based affiliate, has catalyzed many other revolving credit funds aimed at PV consumer financing. Provincial development organizations such as ADEPE (the Association for the Development of the Espaillat Province in the Dominican Republic) and cooperatives such as COMARCA (the Marcala Coffee Cooperative in Honduras) have added PV financing to their regular microenterprise lending.

SELCO

An example of the linkage between a for-profit product supplier and a for-profit financier is the SELCO India / Syndicate Bank relationship. SELCO India, a for-profit subsidiary of SELCO International, supplies RE systems in southern regions of India. For sales beyond the cash market, SELCO has linked with the Syndicate Bank, a local banking institution with 1,600 branches and many programs aimed at rural customers. The Syndicate Bank provides three- to five-year loans to consumers for 90% of the cost of systems sold and installed by SELCO, charging a "priority-sector lending rate" of 12%-12.5%. This linkage is the first involvement of a commercial bank in PV system financing in India. Along with the cash and bank-financing options, SELCO offers customers financing directly through a World Bank line of credit. It also offers a lease-to-own option, with the financing provided by nonbanking financing companies, which receive tax benefits. SELCO also works with local rural institutions such as cooperatives, which offer system financing for their members.[15]

by handling the delivery of both the hardware and the financing internally. This could also be done by a new organization dedicated to both hardware and financing. Having one organization responsible for both the financial and technical system aspects of RE system deployment helps ensure that after-sales system performance will be a priority. Thus, there is a built-in incentive to maintain high standards of equipment performance and customer service. In addition, the all-in-one approach eliminates problems arising from a discrepancy in priorities or modes of operation between two organizations.

The combined strategy also has potential disadvantages. It requires that established organizations become significantly involved in at least one major area of activity in which they do not necessarily have experience. Financial organizations, even rurally focused ones, may not be sufficiently technically oriented to handle RE system installation and maintenance. Likewise, RE equipment suppliers will not necessarily have financial and rural development personnel suited for the complexities of rural credit-fund management.

An extension of the all-in-one strategy is leasing. In this case, ownership of the RE system remains with the system provider until the system is fully repaid. This reduces the risk to the credit provider as it ensures recovery of the system salvage value in case of default. In addition, it reduces the risk to the end user because it is in the interest of the RE supplier to ensure that the system remains fully operational until the item is fully repaid.

Matching credit and equipment suppliers can also pose challenges for each; however, these potential problems may be less severe if the lessons learned from pioneering experiences are incorporated in the planning process. A bank or credit organization involved in small-system financing is dependent on the integrity and follow-up capability of the hardware provider. If a system fails, the financier tends to be the entity facing a default in payments. Covenants or performance-based payment agreements between the two organizations can mitigate the risk to both financier and customer. The credit organization can also establish criteria for qualifying suppliers for access to end-user financing or for establishing portfolio limits. Such decisions are based on criteria such as time in business, level of commercial sales, and credit activity with the organization or other lender. Similarly, a supplier who is not in a position to provide its own credit may find the growth of its business constrained by the financial or organizational capacity of the financing entity.

Several types of organizations have used all-in-one strategies, including for-profit companies, NGOs, and rural electric cooperatives. For-profit companies that combine end-user credit and technical support for RE system installation include Soluz Dominicana, SELCO Vietnam, and RESCO Sri Lanka.

Energy Services Companies

Energy services companies can provide microenterprises with RE systems under a fee-for-service agreement by which the ownership of the equipment remains with the ESCO. A

Grameen Shakti

Grameen Shakti of Bangladesh is an example of a nongovernmental organization involved in both the financial and technical aspects of system dissemination. Grameen Shakti has been installing PV and wind systems on a credit basis for non-Grameen Bank members since 1996, offering financing for up to 24 months.

Soluz Dominicana

Since 1994, Soluz Dominicana, a majority-owned subsidiary of the U.S.-based SOLUZ, Inc., has been providing systems on a fee-for-service basis—financing systems through fixed monthly payments for basic electric service—or on short-term credit. Soluz Dominicana installs and provides all maintenance for small, stand-alone PV systems, as well as a small number of pilot wind systems, for rural households and small businesses in the Dominican Republic.

CRE

Some rural electric cooperatives that already deliver energy services for monthly fees have turned to stand-alone PV systems for more dispersed customers, offering the latter both the systems and the financing. One example is CRE in Bolivia, which began installing PV systems in 1995 on a fee-for-service basis. By 1998, it was serving 1,300 rural customers.

number of private companies, "wireless utilities," and rural electric cooperatives are emerging around the world to provide ESCO services.

The fee-for-service arrangement tends to be strongly preferred by end users because it eliminates the risk to the end user of technical failure of the system. It is in the best interest of the ESCO to ensure prompt and complete maintenance of the systems. In addition, it eliminates the need for the end user to undertake a large capital investment. Soluz Dominicana, a leading PV ESCO, has had a tremendous response to its fee-for-service offering.

Organizations that undertake ESCO operations also take on a level of risk not faced by sales operations. For example, a crucial component in the life-cycle cost of all solar- and wind-based household systems is the treatment of the battery. Because the battery is stored at the end-user site, there is little the ESCO can do to prevent mistreatment of the battery.

Microenterprise support organizations that do not want to handle the full delivery of both hardware and financing may want to consider forming an alliance with ESCOs willing to provide both of these components. Microenterprise development organizations can play a crucial role in financing and supporting the productive applications that are enabled by the electrical services of a local ESCO.

CHAPTER 6. INSTITUTIONAL APPROACH NO. 2: FINANCING AND PROMOTING THE PRODUCTIVE APPLICATION OF ENERGY IN COMMUNITY-SCALE SYSTEMS


Winrock International / 02618849

Figure 6.1. WIND Indonesia wind hybrid system

Introduction

The previous chapter discussed how entrepreneurs, when provided with financing and institutional support, could obtain and utilize their own power generation system to improve their business. However, power generation is often more cost effective when economies of scale come into play. Community-scale systems spread the cost of the power system among many end users and effectively finance the capital cost over years or decades. Such arrangements are possible when:

1. There is a critical mass and density of end-user loads.

2. Long-term financing is available for a power generation project.

3. There is a sufficient institutional capacity in place to ensure cost recovery and management.

Table 6.1. Highlights of Institutional Approach No. 2

Community-Based System	Operator	Customers	Pros	Cons
Microenterprise Zone	• MFI • NGO • ESCO	• Microentrepreneurs • Local MFI or NGO office	• Target income generation • Control over load	• Requires moving existing enterprises to a new site
Minigrid	• ESCO • Electric cooperative • Utility	• Microentrepreneurs • Households • Community loads	• Services loads that are site-specific • Includes residential and community benefits	• Load growth • Repayment not necessarily linked to income generation • Requires additional investment in grid

02618814m

As with distributed individual-system approaches, community-scale arrangements can be implemented by either an exceptionally capable MFI or microenterprise development organization; they can also be done through a strategic alliance with a partner whose specialty is energy provision. Community-scale systems include microenterprise zones, which provide a single facility where energy is provided to microentrepreneurs on a fee-for-service basis, and minigrids, where energy is provided via an electric grid to a host of end users (microenterprises, community buildings, and households, among others).

Microenterprise Zones

One example of a community-scale renewable energy service that can be implemented by an MFI, an NGO or an ESCO is a microenterprise zone, or MEZ.

An MEZ is a facility powered by a centralized electrical system that serves a strategically located cluster of microenterprises in an area without access to an electric grid. The MEZ can function as both a business incubator and a permanent business haven conducive to nurturing income-producing activities in rural, lower-income areas. Physically, an MEZ can be a market-type structure with separate locales for various microenterprises serving the local market or producing products for markets outside of the community.

Concentrating the nonhousehold loads in one area can lead to cost savings in technologies that have economies of scale such as wind turbines and diesel or gas generators. An MEZ also economizes on maintenance by concentrating it in one area. The clustering of the loads within a single structure yields opportunities for good load management to hold down energy system costs. The operator can mandate and ensure efficiency in the loads and orchestrate higher consumption loads to coincide with the availability of the energy resource. This reduces the need for oversizing the peak capacity of a power system. For more information on load management, see Chapter 4.

The minimum service an MEZ can provide is reliable power during extended working hours. However, the concentration of microenterprises lends itself to a variety of business support activities, including microenterprise assistance, microfinance banking, and a higher quality, more stable working environment. The economies of scale from clustering may make a public telephone or fax, photocopying services, or child care more affordable. In addition, synergies in the various productive activities within the MEZ may lead to mutually beneficial business development. For example, the MEZ may become a mini-export production zone or a one-stop shop for local customers.

MEZs require the following:

- Sufficient energy system financing
- The flexibility to move decentralized enterprises to a central area
- Institutions with the capacity to carry out both the technical and business development tasks included in an MEZ.

Renewable-Energy-Based Minigrids

A variation on the MEZ concept is to extend a small minigrid around the MEZ. A grid could provide electricity for a market or commercial area. The lines could also serve productive uses that cannot be transferred to the zone site. These benefits need to be weighed against the disadvantages of increased cost, loss of control of the load, and a possible emphasis on residential uses rather than productive uses of electricity. A useful document on low-cost electric grid construction is *New Designs for Rural Electrification* by the National Rural Electric Cooperative Association.

Grameen Shakti Microenterprise Zones

In Bangladesh, Grameen Shakti has developed four wind-diesel hybrid systems to be used in microenterprise zones on the coast. The zones occupy Grameen Bank-owned cyclone shelters that were underutilized. After several months of monitoring the performance of the systems, project developers invited bank members and other local microentrepreneurs to open small businesses on the premises. These microenterprises use the electricity on a fee-for-service basis. At the same time, bank members take advantage of services at the bank offices housed in two of the sites.

April Allderdice / 02618855

Figure 6.2. Grameen Shakti MEZ turbine

In preparation for this project, Grameen Bank members and staff from the area were interviewed to obtain their ideas about the need for and application of the microenterprise zones. The following recommendations were then incorporated in the planning process for the installations:

- The members were willing to operate their businesses at the cyclone shelter (rather than at home) if it meant that the cost of the power would be much less than power from a minigrid.
- Many of the members had skills and business ideas that would take advantage of electricity, with little further training; however, the skill level of the members varied greatly from region to region. Skills in handicrafts and manufacturing were more prevalent in areas that were generally more affluent and where the Grameen Bank had been active for a longer period of time. Members that relied chiefly on agriculture and livestock for their businesses tended to live in less affluent regions and areas where the bank had become involved more recently.
- The staff members were able to evaluate which electricity-using businesses would be most lucrative in their areas, and were well versed in how to facilitate Grameen Bank loans for the necessary equipment.
- The staff had insufficient lighting for the paperwork they needed to complete.

One of the opportunities that Grameen Shakti faces is the seasonally variable wind speed in Bangladesh. Although the systems are designed with back-up generators to reliably meet their design load, the zones will be able to operate most cost effectively if they can utilize the greater wind resource that exists during the summer (monsoon) months.

Load/Resource Matrix Technique for MEZ System Selection

Designing an MEZ can be a time-consuming process. Even when sufficient technical expertise is available, design efforts can be thwarted by the difficulty of ascertaining data about prospective loads and energy resources. A load / resource matrix is a tool that can be used to simplify system design while providing a reasonable number of options to MEZ developers.

In the sample load matrix shown (see Table 6.2), several hypothetical MEZs were created. Each MEZ incorporates a combination of common microenterprises in the Dominican Republic. The hypothetical MEZs were then classified by their average monthly energy requirement. Optimal system designs for each of the four load classes were then established using the hybrid design tools, HOMER and Hybrid 2. The analysis used country-specific data on the cost and availability of components, local fuel price, and solar insolation data. Separate designs were generated for each of the load classes in three different wind regimes. A sample matrix (see Table 6.3) shows least-cost designs for load levels from 200 to 800 kWh / month and wind speeds from 4.0 to 6.0 m / s.

The matrix can be a useful tool in making initial decisions in situations where an exact optimization is neither possible nor meaningful. The initial systems can then be fine-tuned over time as the loads are implemented and the MEZs begin to grow. Some of the issues that need to be considered in the development and utilization of matrixes are exceptionally large loads that may alter the peak capacity needs, and surge capabilities of power equipment.

Table 6.2. MEZ Load Matrix

	kWh/month										
Cafe I	133				x	x	x	x	x	x	x
Cafe II	68	x	x	x							
Small Store	75	x				x				x	x
Cinema	20	x						x			x
Laundry	174			x	x	x	x	x	x	x	x
Beauty Salon	123			x		x		x	x	x	x
Carpentry Workshop	144						x		x	x	
Electric Workshop	36	x	x	x	x	x			x		x
Fish Store	98		x					x		x	x
Community Center I	59				x	x		x		x	
Community Center II	149						x				x
TOTAL (kWh/month)		200	200	400	400	600	600	600	600	800	800

02618813m

Table 6.3. MEZ Loads/Resource-Sizing Matrix

	6 m/s Wind Speed	5 m/s Wind Speed	4 m/s Wind Speed
200 kWh/month	• 1 kW Wind • 2.3 kW Gas Generator • 8.4 kWh Battery Bank	• 1 kW Wind • 2.3 kW Gas Generator • 16.8 kWh Battery Bank	• 740 Wp PV • 2.3 kW Gas Generator • 16.8 kWh Battery Bank
400 kWh/month	• 2 kW Wind • 4.8 kW Diesel Generator • 16.8 kWh Battery Bank	• 1200 Wp PV OR 2 kW Wind • 4.8 kW Diesel Generator • 33.6 kWh Battery Bank	• 1200 Wp PV • 4.8 kW Diesel Generator • 33.6 kWh Battery Bank
600 kWh/month	• 3 kW Wind • 7.5 kW Diesel Generator • 33.6 kWh Battery Bank	• 3 kW Wind • 7.5 kW Diesel Generator • 33.6 kWh Battery Bank	• 7.5 kW Diesel Generator • 33.6 kWh Battery Bank
800 kWh/month	• 4.5 kW Wind • 7.5 kW Diesel Generator • 50.4 kWh Battery Bank	• 4.5 kW Wind • 7.5 kW Diesel Generator • 50.4 kWh Battery Bank	• 7.5 kW Diesel Generator • 50.4 kWh Battery Bank

Sample configurations for microenterprise zones of different load sizes in a region where solar radiation is constant but wind speed varies from location to location

02618812m

Productive Uses of Electricity Programs with Renewable Energy Service Companies or Cooperatives

Not all MFIs and microenterprise support organizations will be able to implement their own MEZ or minigrid. By working with a utility, electric cooperative, or ESCO, MFIs can both influence the process of electrifying their community and assist microentrepreneurs in using the electricity to benefit their businesses.

Through a program focused on productive uses of electricity, an MFI can provide credit for electric tools or machines vital to translating energy into income generation. MFIs and microenterprise development organizations that provide nonfinancial services may be well positioned to provide training, market development, and other services to customers to further leverage the benefit achieved from the energy resource. Productive uses of electricity programs can fit well into an MFI's credit or leasing activities for several reasons. As the electrical machines or appliances are clearly income-generating items, they pose less of a need for modifications to MFI lending practices than do the power systems themselves. In addition, as an ESCO or cooperative provides power on a fee-for-service basis, the microentrepreneur is relieved of the burden of a large capital investment in generation equipment. Thus, poorer members of the MFI may be able to benefit from the program.

Project ENSIGN — Financing Energy Services and Income-Generating Opportunities for the Poor

This UNDP-funded ENSIGN program, coordinated by the Asian and Pacific Development Center in Malaysia, included 24 pilot projects in seven Asian countries. These projects provided modern energy services targeted to income-earning activities in 219 households in India, Indonesia, Mongolia, Myanmar, Nepal, Philippines, and Sri Lanka. Most of the activities were based on grid electricity, although some used solar PV or other sources. The majority of the activities were cottage industries producing items such as bangles, bottle caps, mattress covers, envelopes, and garments. Others included services such as grain grinding, auto tire air-filling, and rice hulling. Project-wide, the average income growth was 53%, increasing monthly income from an average of $63 (U.S.) / month to $96.5 (U.S.) / month. One of the participating organizations, the SEWA Bank in India, has already begun to integrate ENSIGN-type loans into its mainstream lending.[17]

Two examples of productive uses of energy programs are given here. These relied mainly on grid extension for their electrical sources; however, the results of these programs could have

El Vinto Productive Uses Program

The El Vinto Densification Project was implemented by the National Rural Electric Cooperative Association, ELFEC (the local utility), and PRODEM (a microfinance organization) to promote productive uses in the lower Cochabamba Valley of Bolivia. About $100,000 was invested in service drops and line extensions. Another $103,000 was loaned for 83 productive uses. The loan amounts varied from $66 to $6,500; 77 of the loans were for less than $1,000. Shortly after making the loans, PRODEM sold the portfolio to BancoSol, allowing NRECA to invest the money in another productive-uses project. However, financial analysis (projected out to 20 years) for the service drop component of the project showed a loss. The main reasons were the low average end-user consumption of only 36 kWh / month, and the high administrative cost that ELFEC charged the project. Eighteen of the 83 productive uses that benefited from the loans were surveyed in a final evaluation of the loan component of the project. All but one showed an increase in production. Similarly, all but one showed an increase in profit, though it was not the one that had reduced production. The 18 productive uses surveyed generated a total of 25 new jobs.[16]

been as easily achieved with a remote hybrid minigrid fueled by renewable resources.

Financial Sustainability in a Community RE System

Like microfinance banks, electric cooperatives and utilities can provide reliable, long-term service only when they are financially sustainable. In both MEZs and minigrids, the developer retains ownership of the energy system. If the developer of the MEZ is a bank, NGO, or ESCO, it may have access to more favorable terms for energy system financing than would a microentrepreneur. Sources of finance for MEZs may include the following:

- Governmental rural electrification funds
- Renewable energy lines of credit
- Local or regional development bank loans
- Donor agency programs
- Private investors.

The Impact of Load and Load Growth

Having sufficient load, and the associated tariff payments, are vital for a financially sustainable system. Some ESCOs, utilities, or electric cooperatives may be unwilling to consider an area because of a perceived lack of load potential. Although microenterprises do not consume energy on the level of large industries, they usually require greater amounts of power than residences. Moreover, they contribute to the economic development of a community, a process that leads to greater electricity consumption in general. For these reasons, a microenterprise organization may be able to encourage ESCOs, utilities, and electric cooperatives to provide power in their areas by demonstrating the needs of their constituent microentrepreneurs.

The presence of electricity in a community generally leads to significant load growth over time. Depending on the power system, this load growth can have disparate impacts, such as the following.

- Wind or PV-battery hybrid systems: If there is no dispatchable backup source of power, load growth can overwhelm the system's capacity, causing failures.
- Hybrid systems with diesel backup: Load growth may lead to excessive use of the diesel, shortening its lifetime and increasing fuel costs. Load growth beyond the capacity of the system will cause failures.
- Micro-hydro: Increased load reduces the unit cost of electricity up to the capacity of the power station, but will cause system failures if it exceeds the capacity.
- Grid extension: Increased load reduces the unit cost of the grid extension up to the installed capacity of the grid lines.

In an MEZ, load growth is easy to manage because the operator can decide what new enterprises are allowed to be connected. The enhanced control also makes it easier to design tariffs appropriately so that the applications do not have to be limited. With a minigrid, the operator has less control over new loads that are added within individual households. Some minigrid operators install current-limiting fuses in households to ensure that loads do not exceed manageable levels.

Setting an Appropriate Tariff

One way to manage loads is to design an appropriate tariff to encourage reasonable amounts of energy use. An end-user fee may be collected through metering, by using a fee schedule that varies according to the type of equipment used, or by charging a fee per connection, and limiting the available power by using a current-limiting device.

A tariff that is sufficiently high may deter users from consuming more power than necessary as well as provide sufficient income to justify an expansion of the power system as the load demands it. Some systems (such as micro-hydro stations) may not have the natural resources necessary to increase the capacity of their power station, however. Many organizations include a cross-subsidy within the tariff structure to ensure that poorer customers are also able to benefit from the electricity. A project that focuses on microenterprise development may prefer to provide service to microenterprises even when wealthier residential customers are willing to pay more for the power.

CHAPTER 7. INSTITUTIONAL APPROACH NO. 3: SUPPORTING ENERGY ENTREPRENEURS

Because energy is in high demand in areas with no grid electricity, innovative microentrepreneurs often seek ways to make a profit by selling electricity and energy-related products to their fellow villagers. Small, rural retail stores sell dry-cell batteries, flashlights, kerosene, candles, and butane lanterns to local households. Some individuals with generators connect households to sell electricity; others sell battery-charging services. As renewable energy has become better known in rural areas, these “energy entrepreneurs” have also made use of renewable energy systems as a means to meet customer needs and develop business.

In spite of their many different approaches, energy entrepreneurs share some elemental advantages over other energy service providers. Microentrepreneurs usually live in the communities that they serve. They are personally impacted by the quality and reliability of the energy service product, which legitimizes their marketing claims in the eyes of their customers. In addition, the customers know that the entrepreneur will be available with little notice to provide technical assistance and customer service. Thirdly, microentrepreneurs usually operate with very small overhead margins. For example, they may conduct business out of their homes. They may avoid high transportion costs, as they live close to the communities they serve. Larger companies may need to invest in uniforms and marked cars to establish their name recognition, while microentrepreneurs are often already known in the community.

The "micro-" nature of the energy entrepreneur also creates its greatest vulnerability: its dependence on the community. If the community's demand for energy service drops off, the microentrepreneur is not able to shift to another community. The business viability of an energy entrepreneur depends on sustained need and the community’s willingness to pay for electric service. While it is ultimately the microentrepreneur's responsibility to accurately evaluate the potential of the business, this may be very difficult to do in a community where there is no comparable service. In such cases, community members' assertion of their demand for energy can be critical in the decision to start. In other words, the entrepreneur and the community essentially create a covenant in which both parties have responsibility for the successful energy service business. Entrepreneurs can try to formalize this covenant through the establishment of community committees, membership fees, or service contracts. Regardless of the mechanism used, care must be taken to clearly convey the importance of the commitment to community members who may be less predictable participants than the entrepreneur.

Table 7.1. Highlights of Institutional Approach No. 3

Energy Entrepreneur	Microfinance for Entrepreneur	Microenterprise Support for Entrepreneur	Microfinance for Community	Microenterprise Support for Community
Battery-Charging Station	• Initial plant	• Technical training • Licensing • Covenant for energy service provision with community	• Finance for battery (if needed) • Productive DC applications	• Promoting productive applications of electricity
Mini-Utility	• Initial plant		• Finance for productive applications	
Retailer	• Working capital for inventory, operating costs		• Finance for individual RE systems bought from retailer	

02618817m

SGA Energy Ltd., Ottawa, Canada / PIX07912

Figure 7.1. Battery-charging station

Battery-Charging Stations

What Is a Battery-Charging Station?

Battery-charging stations use a central power source to charge portable batteries as needed. The batteries are used in customers' homes to power television sets, lights, or other loads. Customers can pay per charge or a set monthly fee for a certain number of charges. Other electrical equipment, such as electronics for battery protection, may be provided by the user or by the BCS enterprise.

The Advantages of a BCS

Centralization of the power system can capture the economies of scale offered by renewable energy technologies such as wind and hydroelectric, as well as diesel generators. A BCS also takes advantage of economies of scale in administration and operation and maintenance. It can centralize technical aspects of energy production and equipment maintenance with the power system located in a secure location near the target market. A locally based representative or entrepreneur can perform the necessary maintenance along with operation.

As with users of other RE technologies, BCS users enjoy the benefits of a smoke-free household and better quality of light. Electric systems also reduce the likelihood of fire caused by tipped lamps. In addition, a locally situated BCS is also more convenient than a distant, grid-powered one. For users, the low level of commitment—particularly with per-charge fees—means that a BCS can closely match what customers might have paid previously for battery charging, kerosene, or dry cells.

Fee Payment Structure

As the capital cost for a renewables-based BCS is much higher than that of a grid-connected BCS, the user fees are likely to be higher, and the investment may have a longer payback period. The BCS operator may choose to take payment on a per-charge basis, or may employ a monthly subscription plan. The latter offers more security, because the customers make a commitment to a certain number of charges per month.

Photovoltaic Battery-Charging Stations versus Solar Home Systems

Battery-charging stations work best with technologies, such as wind turbines and hydroelectric or diesel generators, that benefit from economies of scale. In the case of photovoltaics, the quality of service from a BCS is much the same as that from a solar home system.

Teotonio Vilela Foundation

For-profit project developers can link with other entities, including nonprofit organizations, government agencies, and local entrepreneurs to provide efficient, cost-effective service via a renewable-energy-powered BCS. The Teotonio Vilela Foundation (FTV) launched a program in 1996 to help energy entrepreneurs administer a photovoltaic BCS financed by the U.S.-based Golden Genesis Company and the Northeast Bank of Brazil. Under the *Luz do Sol* program, entrepreneurs from each community manage the systems installed by FTV, taking responsibility for collection, administration, and operation of each BCS and paying for the systems over time.

Transportation of batteries can be inconvenient, and carelessness may harm the batteries. Although batteries may reach full states of charge regularly and predictably (each time they are brought to the BCS), the battery life can be significantly shortened because customers will usually want to drain them as fully as possible before recharging. A low-voltage disconnect incorporated into the battery or in-house wiring can mitigate those effects to some degree.

In spite of these drawbacks, photovoltaic BCSs may make sense in off-grid situations where:

- Demand for many customers is lower than the amount of energy offered by standard stand-alone systems
- End-user financing is scarce
- The BCS is used as a transitional phase or in conjunction with stand-alone system dissemination
- The BCS institutional structure provides the necessary income for a maintenance and customer service entrepreneur that cannot be developed through an SHS program.

Hugo Arriaza / 02618856

Figure 7.2. Micro-hydro is commonly used to supply minigrids.

Institutional Structure of the BCS

The batteries can be owned by the BCS operator / administrator or by the individuals. There are advantages and disadvantages to each option. On one hand, BCS ownership facilitates standardization of the batteries, can allow for bulk purchasing of the batteries, and can ensure regular battery maintenance. This avoids the technical difficulty of charging batteries of different specifications, lifetimes, and characteristics. However, customers may mistreat or over-discharge the batteries at home or in transport.

IT Peru — Lending for Mini-Utilities

IT Peru, an affiliate of the U.K.-based Intermediate Technology Development Group (ITDG), has developed a successful program that provides financing to develop micro-hydroelectric mini-utilities in rural areas of Peru. A nonprofit organization, IT Peru used long-term concessional financing from the Inter-American Development Bank (IADB) to start a revolving loan fund for micro-hydro and to leverage many additional funds. By 1998, the organization had financed 15 systems, including 5 for individual clients and 10 for communities, with five-year, 8% loans for $10,000 to $50,000. Financing was an important factor in allowing communities to access the technology. IT Peru set up "Credit Operators" to handle the analysis and administration of the loans and to separate the financial decisions from the technical and organizational ones.

Because of the high dispersion rate in the target market, IT Peru chose to aggregate the larger power loads in central locations and avoid the cost of minigrids, as in the MEZ concept. Thus, the hydro systems powered on-site grain mills, for example, while providing battery-charging for the dispersed domestic market for lighting, radio, and television.

When, despite its innovations and the relative successes of its financing plan, IT Peru still found that the rural communities could not fully cover the costs of the energy systems, it was able to leverage the financing plan with municipal grants to cover the total system infrastructure.[18] More information about the ITDG Program is given in the case study section.

Individual ownership of the batteries, on the other hand, can lead to greater user responsibility with regard to battery use and abuse, and shifts the responsibility for maintenance onto the customer.

From the point of view of the local entrepreneur, a single BCS can be a sustainable, profitable operation. The entrepreneur might require access to financing and technical assistance, but can otherwise be self-sustaining.

Mini-Utilities

What Is a Mini-Utility?

A second type of energy entrepreneur extends electric lines to neighbors, creating a local, decentralized mini-utility. The owner charges a fee based on the expected loads, such as a monthly per-bulb fee. Usually these arrangements involve quantities so small that they do not warrant the cost of meters; although, for systems of sufficient size, metering can provide a more accurate distribution of cost. These schemes are likely to be effective with renewable energy systems based on wind or hydroelectric generators, where economies of scale (or product availability) may lead to purchase of systems larger than necessary for the primary user.

Mini-Utilities and Energy Efficiency

Mini-utility entrepreneurs can benefit from learning about energy-efficient products. For example, a supplier able to serve 10 households using 100-W incandescent bulbs will be able to

Enersol Training Program

Would-be solar entrepreneurs in the Dominican Republic trained by Enersol Associates or ADESOL were subsequently provided access to end-user financing for their customers to help them gain experience. Enersol and ADESOL not only trained the entrepreneurs in the technology design, installation, and maintenance, but also touched on business development and microenterprise management. Such skills training may make the RE retailers more appealing for working capital loans from microfinance organizations, as happened in certain cases in the Dominican Republic.

Gabriel/02618857

Figure 7.3. South Africa solar shop

Biogas Support Program Standardization

Although this guidebook focuses on electrical energy, valuable lessons can be learned from a biogas development program in Nepal. The Biogas Support Program of the Netherlands Development Organization (SNV) and the Government of Nepal trains and licenses biogas-digester suppliers. The program prescribes the exact dimensions and materials of every size system and enforces them through follow-up checks. The improved reliability of the biogas digesters helped catalyze market penetration to more than 20,200 customers between 1991 and 1997. Although the suppliers benefited from the legitimacy they acquired through participating in the program, not all of them appreciated the increased competition. By standardizing the design so stringently, this method has reduced the ability of different suppliers to compete with each other based on their design. By 1997, two of the licensed companies had closed their businesses because of diminishing returns. However, this method protected the consumer and led to a growth in both the number of suppliers and the size of the market.

serve 66 households using 15-W compact fluorescent bulbs providing the same quantity of lumens.

Regulatory Environment

Entrepreneurs in some countries may be faced with prohibitions or restrictions concerning the sale of power. Some countries offer concessions to private energy developers to be the sole providers of electric services in a particular area. Other countries provide a monopoly to a governmental or quasi-governmental utility. In some cases, the law requires electric service providers to meter and charge on a consumption basis, or to set electric tariffs at a particular rate.

RE System Retailers

What Is an RE Retailer?

Energy microentrepreneurs can take the form of local renewable energy system retailers / installers. These operations may employ as few as one to three employees, require under $5,000 in working capital, and benefit from being based close to the rural market they serve. Such entrepreneurs can be crucial links in the renewable energy product and financing delivery chain, particularly in markets not served by larger businesses. Many rural PV technicians have emerged throughout the world who sell small PV systems for $500 to $2,000 each and install perhaps 2 to 10 systems per month, managing to make a decent income from this service in the process.

Training, Licensing, and Standardization

Training, licensing, and standardization can help strengthen RE system retailers, the market's acceptance of their product offerings, and their access to financing.

The Role of Working Capital

Microfinance in the form of working capital loans can be important to the RE system retailers who serve the rural markets. Solar retailers may be able to sell single systems with little inventory by obtaining credit from distributors, paying off the credit after receiving payment for each installed system. The accumulated profits eventually allow the retailers to maintain a small inventory of system components. Microfinance loans for working capital may help accelerate RE retailers' businesses, allowing them to keep inventory, expand their retail or storage spaces, ease transportation to reach clients, and equip themselves more fully with tools and other materials.

Microfinance to rural customers of energy microentrepreneurs can help expand the market size for RE products. The existence of a microfinance program for RE can also shift the burden of providing end-user finance from the entrepreneur to the microfinance institution.

Noor Web — Blending Approaches

In Morocco, an innovative melding is occurring between the three types of energy entrepreneurs. Noor Web is offering a franchise for renewable energy businesses, which offer services combining the three models presented earlier. These businesses will offer battery-charging services from their in-house PV systems, retail solar home systems, lanterns, electric tools, appliances, and maintenance supplies; they may also house a PV utility company. In the future, such stores may offer complementary income-generating activities, including movie showings and telecommunications. The franchise approach offers business training, access to financing, and connections to equipment suppliers to support and strengthen the entrepreneurs.

CHAPTER 8. CASE STUDIES

Introduction

This chapter presents six case studies. In some cases, a description of a benificiary entrepreneur's business is given. This is followed by a description of the institutional framework that empowered the entrepreneur to access renewable energy. Each case highlights a different interpretation of the institutional approaches described earlier in the guidebook. Combined, these cases provide valuable lessons that can be used in designing future programs to provide energy access to microentrepreneurs.

Grameen Shakti: Providing Energy Services within a Microcredit Framework in Bangladesh

Hanif is a sawmill operator in the small village of Dhalapara in central Bangladesh. Hanif earns $0.20 per cubic foot for sizing timber brought to him by local villagers. He normally is able to size 200 cubic feet per day, earning $548 per month after the salary of his assistant and the cost of fuel for the diesel-powered mill are subtracted. In 1997, Hanif was able to take advantage of a Grameen Shakti program that provided solar energy systems on credit. For $270, Hanif was able to purchase a 17-W PV system including a PV panel, battery, charge controller, and two fluorescent lamps. The system enabled his business to operate an additional four hours per day, increasing his cash flow by 50%. These profits are high enough to repay the system within two months and make his business prosper. He is now the owner of a second sawmill in a neighboring village.


April Allderdice, NREL/02618839

Figure 8.1. A sawmill in Bangladesh gets electricity from PV.

Recognizing the need for electricity for microentrepreneurs such as Hanif, the Grameen Bank embarked on a renewable energy initiative in 1996 by starting an affiliate not-for-profit company called Grameen Shakti. Grameen's experience with several institutional models illustrates the comparative advantages of both the all-in-one and strategic-alliance models for end-user finance of renewable energy systems. Although Grameen's solution most closely fits in the all-in-one category, the final outcome is a hybrid of the two approaches.

From the beginning, the Grameen Bank decided to separate the renewable energy program from the banking program. The renewable energy program needed to be able to stand on its own and would not be allowed to adversely affect the sustainability of the bank itself. Moreover, bank officials were too busy to conduct the time-consuming job of sales, marketing, and system maintenance. As an independent company, Grameen Shakti capitalized on the bank's rural network and reputation as it built its own network around the existing infrastructure.

Although Grameen Shakti had originally intended to target bank members, it soon found that the most eager customers fell in a higher economic class. The wealthier villagers showed the greatest interest because they had greater resources and could more comfortably afford the systems. Also, they tended to be leaders in the community. When they bought a system, the rest of the village would come to look at it and decide if they wanted one. Grameen intuitively found it useful to support this process. Because the customer base of Grameen Shakti was to include this group in addition to the bank members, Grameen Shakti needed to develop an additional financing mechanism to serve these customers.

Realizing that they knew little about renewable energy technologies, Grameen tried to bring private-sector expertise to the project. Two solar suppliers based in Dhaka, the capital, were brought in to design and sell the SHSs through the Shakti network and credit program. Through this process, the Shakti engineers became familiar with the technology. It soon became apparent that Shakti could lower the cost of the systems by putting their own engineers in the field to do sales, installation, revenue collection, and maintenance full time. Grameen Shakti used the bank's approach of hiring low-cost, minimally educated labor, and training them on the job. This labor is much less expensive than the university-educated and city-based engineers employed by the private-sector suppliers. Moreover, this approach sidestepped the expense of travel from Dhaka to the village for every maintenance call.

The Grameen Bank experience is constantly used as a reference in Shakti's development. Relying on their experience with scaling up the bank's branch network, Grameen Shakti did not target the national market from the beginning. The viability of the Shakti program, like that of the bank, depends on the existence of the rural sales and service network. In areas where that network did not yet exist, Shakti did not advertise systems. Rather, Shakti targeted five small regions of the country, within a day's travel from each of their unit offices. Profits from those areas will fuel new units in other areas as sales increase.

In the Bangladesh political environment, removing an SHS from a poor villager's house may bring down negative publicity on the Grameen name. In one particular instance in which a Grameen Shakti customer was unable to repay, Grameen Shakti used a mechanism that Grameen Bank has used with other loans in the past; it transferred the SHS and the repayment schedule to another member of the community. When a Grameen Bank member suffers a setback that makes repayment difficult, Grameen Bank usually tries to transfer the loaned item to another member of the group. In this way, the credit of the group remains strong, and the group retains the benefit of the income-generating item.

By 1999, Grameen Shakti had sold more than 1,000 SHSs from 10 unit offices. The organization's initial successes and links with the strong MFI helped to attract $750,000 in investment from the IFC's Small and Medium Enterprises Program in 1997. In addition to these commercial solar sales operations, Grameen Shakti also developed pilot projects for activities that fall within its mission of developing energy resources for rural microentrepreneurs. One such major research effort was the development of microenterprise wind power zones, which were discussed in Chapter 6. These microenterprise zones provide 24-hour AC power on a fee-for-service basis to entrepreneurs who carry out electricity-utilizing enterprises on the premises. Systems were installed beginning in November 1998.

Global Transition Group: Renewable Energy for and through Microenterprises

Electricidad del Sol

Electricidad del Sol is a PV retail business in Partido, Dajabon, in the northwestern Dominican Republic. Teofilo Cepeda, its


Enersol Associates, Inc. / 02618847

Figure 8.2. Training of Haitian solar technicians

Enersol Associates, Inc. / 02618846

Figure 8.3. ADESOL-supported RE retailer business with wind turbine

founder, proprietor, and sole full-time employee, makes a living selling stand-alone PV systems to rural customers, both microenterprises and households. Along with offering a variety of PV-system sizes for different loads, Electricidad del Sol is able to offer access to third-party financing for PV customers through the company's linkage with the Dominican NGO Association for the Development of Solar Energy, Inc. (ADESOL).

Electricidad del Sol sells systems with about a 20% gross margin. With 50-watt systems priced at around $800 and a low overhead, Cepeda can make a good living selling two to six systems monthly, with supplemental income from cattle-raising. Between 1988 and 1998, Electricidad del Sol sold over 500 systems.

ADESOL

Although many of Electricidad del Sol's clients have paid cash, consumer financing has played an important role in catalyzing the market and extending the microenterprise's reach. That financing has generally come from ADESOL , an organization that promotes innovative energy solutions for nonelectrified zones of the Dominican Republic. The strength of its efforts, particularly in the field of PV, comes from its support of a network of independent PV microenterprises such as Electricidad del Sol. By financing the individual household and small-business customers of the microenterprises through those same enterprises, ADESOL has sought to economically and efficiently join product supply and third-party financing to catalyze microenterprises.

Since its conception, financing has been an integral part of ADESOL's mission. The organization began in 1984 as a small community group—Dominican Families for Solar Energy—organized to seek financing for PV system acquisition. The families used seed money from the local United States Agency for International Development (USAID) mission to start a revolving loan fund to finance initial purchases. ADESOL, in its original form and later as an organized nonprofit, has always worked closely with Enersol Associates, Inc., a U.S.-based nonprofit organization whose founder introduced the first rural lighting system that led to the creation of ADESOL.

Electricidad del Sol's Cepeda has been involved in ADESOL since its expansion beyond the small community group, as a board member and now as president of the board, which is composed chiefly of representatives from different PV microenterprises. ADESOL works closely with the network of small, local PV enterprises—the Solar Network—which provide a crucial product-supply link between importers / distributors and the rural customer base. Many of the enterprises in the country have formed as a result of Enersol / ADESOL training activities, which focus on developing microenterprises and on creating supportive environments within the NGO and government communities. This technical training has led to the creation of approximately 15 independent microenterprises. These small businesses often have only one to three employees, but are well-positioned to serve local rural markets. The businesses procure equipment from any of the country's four to five distributors of PV components and sell complete, installed, and guaranteed systems to households or small businesses for lighting, entertainment, and other electrical energy needs.

ADESOL's limited amounts of consumer financing help support microenterprises. The businesses in the Solar Network access ADESOL credit for their customers and serve as financial intermediaries—qualifying customers, processing loan agreements, charging down payments, and collecting monthly payments after installation. New member businesses have access to small amounts of ADESOL consumer financing initially, then build up their access with a track record of successful deployment and recovery of financing.

ADESOL has tailored its financing to local conditions. In some respects, the terms of the end-user financing match those of other types of financing the rural customers might be able to access. The interest rates, reflecting concerns about devaluation of the Dominican peso, are often as high as 2.5% per month over the original balance—an implied rate of almost 50% for a two-year loan. The term of the loans is up to 24 months—longer than the same customers could typically access for other consumer items such as domestic appliances. ADESOL customers sign contracts indicating that the systems can be removed for nonpayment, yet requires no other guarantee (unlike other lenders). The success of ADESOL's financing, even at high interest rates, demonstrates the significant value of financing in rural markets, as well as the high cost of capital for would-be rural customers for PV.

Enersol Associates, Inc. / 02618845

Figure 8.4. Enersol supports PV for coffee cooperative members in Honduras.

Financing from ADESOL has played a crucial and successful role in extending the reach and increasing the business experience of the Solar Network microenterprises, particularly in the early stages when clients are less inclined to risk investing because of unfamiliarity with the technology. Donations or loans from institutions such as USAID, the Government of the Netherlands, the Global Environment Facility (GEF), and various U.S. foundations have allowed ADESOL to finance systems for more than 600 households and microenterprises through the Solar Network. That financing has accompanied a much greater number of cash sales by the Solar Network and other companies: the microenterprises that ADESOL works with have installed more than 5,000 systems since the mid-1980s, while the total for the Dominican Republic as a whole is approximately twice that figure.

Soluz Dominicana

An outgrowth of the original model microenterprise involved with ADESOL is now one of the country's leading RE companies, Soluz Dominicana, S.A. This company is implementing an important innovation by linking financing and product supply. Based in the north-coast province of Puerto Plata, it offers a PV fee-for-service option to rural microenterprises and households in Puerto Plata and two neighboring provinces. Customers pay set monthly fees for service for any of several complete PV system packages; the company maintains ownership and responsibility for maintenance and repairs. By late 1998, Soluz Dominicana was serving almost 1,800 PV fee-for-service customers.

Soluz Dominicana's customers include a range of microenterprise types, including many small country stores using the energy for lighting, radio and television, thus helping them to attract customers during longer working hours. Soluz Dominicana has also introduced a PV refrigerator package, to meet increasing portions of the stores' energy needs with renewable energy. In some areas, the fee-for-service or retailed PV systems power customers' cellular phones and blenders, products which can easily translate into income generation. Through its wholesale activity, Soluz Dominicana is among the distributors supplying system components to PV system installers in other regions.

Soluz Dominicana has served as a model for operations elsewhere. The company's parent, SOLUZ, Inc., launched a similar operation in northwestern Honduras in 1998, serving rural microenterprises and households through a PV fee-for-service offering. Soluz Dominicana's key personnel have been involved in ramping up the Honduran enterprise to serve large numbers of rural customers.

Enersol, SOLUZ, and a joint-venture consulting firm together form the Global Transition Group, an organizational alliance committed to the global transition to sustainable energy through a variety of rural initiatives and innovations.

Lessons Learned

- **Microenterprises:** Microenterprises play key roles in the growth of renewable energy use. Small PV retailers can be crucial links in the product supply chain between importers and distributors in larger cities and the rural market. Where qualified, retail microenterprises can also be effective conduits for consumer financing, acting as financial intermediaries for client qualification and payment collection. Microenterprises can also be important, early adopters of PV technology because of the more immediate return on their investments in higher-quality energy services.

Paul Wormser / 02618851

Figure 8.5. SOLUZ customers in Honduras sewing under light from a rented PV system

- **Sustainability:** ADESOL and Enersol have consistently emphasized full-cost recovery in financing to make the most efficient use of scarce funds and help attract more commercial money to the financing effort. Working directly through local microenterprises has helped strengthen those businesses' ability to supply systems and operate their businesses responsibly.
- **NGO All-in-One Financing:** In some cases, NGOs that have set up revolving credit funds with help from ADESOL have used them in ways that have undercut, rather than strengthened, local PV microenterprises. In particular, this undercutting has occurred when the NGOs used grant funds to subsidize marketing, sales, and installation of the PV systems, rather than offering just financing and promotion. These practices appear to risk hampering the development of the local market as a whole.
- **Fee-for-Service:** Soluz Dominicana's fee-for-service strategy can be an effective way to combine product supply and financing within a commercial framework, bringing the necessary capital to bear to reach a significant portion of unelectrified rural microenterprises and households.[19]

Winrock International: Community-Based Power for Microentrepreneurs in Indonesia

An onion grower in Indonesia was accustomed to working 1,040 hours per season, hauling water to irrigate his crop. These efforts produced a crop valued at $550. Using a wind-powered community water pump, this farmer was able to increase his crop and his income fourfold and reduce his labor to 100 hours per season. In return for the water service, the farmer pays a fee of $0.10 per cubic meter of water used to the community committee that manages the water-pumping system. This amounts to about $40 per month in expenditures during the six-month dry season. His profit of more than $1,400 per season makes the cost worth it, particularly for his children, who can now attend school rather than work in the fields.

This community wind pump and nine other community-based wind energy systems were made possible through a market development initiative of Winrock International, Wind for Island and Nongovernmental Development (WIND).

Policy Framework

The purpose of the WIND project is to strengthen the local capability to adapt wind-based energy technologies to numerous applications. The project endeavors to build a sustained interest in renewable energy and the potential for economic development that it can bring to a rural area. As the microenterprises build their capability to utilize renewable energy, they create a market for future renewable energy development. By demonstrating that the cost of the systems can be recovered through end-user fees, project managers hope to attract private-sector investments in energy enterprises. Private-sector development of renewable energy would create a sustainable means of providing power to fuel long-term rural economic development.

Funding

USAID provided funding to Winrock International to develop 10 windpower sites in Indonesia as part of its contribution to the GEF. Winrock was the ideal candidate based on its long experience working in the region and the existence of nearby Winrock programs that also support and develop microenterprise.

Institutional Mechanics

As of February 1999, nine community-operated wind energy systems had been installed. Each system has a working group, made up of local technicians who carry out the routine maintenance and customer service tasks. When possible, an NGO is involved in the project to conduct the revenue collection and fund the working group. The end users are responsible for a service fee, which is metered according to energy usage or volume of water. The NGO assumes responsibility for revenue collection and receives 15% of the fees as operating costs. The remainder of the fees are put in a maintenance account. Once the account reaches a certain amount, the funds are used to expand the system in a manner that the community decides. In a few situations, an NGO could not be identified to assume responsibility for the systems. In those cases, a community committee is formed to assume the responsibility. In general, it is easier for an NGO or a committee to collect payments rather than an individual because in these villages, it tends to be culturally inappropriate for an individual to press friends or family for payment, whereas an NGO is sufficiently impersonal to complete the task.

Technical Systems

The systems use 10-kW and 1.5-kW Bergey Windpower Company, Inc., energy systems. Each system includes a wind turbine, at least one inverter, a diesel backup, and a battery bank.

Applications

- **Irrigation**—Six of the sites use wind energy for irrigation. In these cases, entrepreneurs use the water to diversify their agricultural activities to include high-priced vegetables, citrus, or lumber, or to merely increase their present activities. The citrus growers had access to a microenterprise assistance program, which taught them to select products for size and consistency, establish efficient transportation links to the urban market, improve the freight packaging, and develop a brand name for the produce. One vegetable grower increased her production and profit fivefold.

- **Ice-making**—Several entrepreneurs used the electricity to make ice for sale to local fishermen. The availability of ice enabled the fishermen to store their catch until the market demanded it. Fishermen are now able to avoid the middlemen who took advantage of their lack of options, and now sell to trawlers that take their products as far as South Africa.

- **Other Application**s—One of the priorities of the WIND project was to develop a wide range of capabilities when applying renewable energy. Entrepreneurs use the systems for a wide variety of applications from power tools to corn grinding to chick incubation. As these local communities develop technical capacity in these enterprises, they also increase their ability to reap economic growth from renewable energy resources.

Intermediate Technology Development Group: Financing Micro-hydro Entrepreneurs in Peru

The El Tinte cooperative in Peru produces fresh milk for a distribution company called INCALAC. They have four cows and produce about 500 liters of milk per day. Before they installed their micro-hydro power plant, they milked the cows by hand and carried the product to cool in the river. The inconsistent quality of milk this method produced resulted in a low purchase price of $0.06 per liter rather than the full price of $0.11 per liter. The addition of energy has improved the productivity of their enterprise in several ways. They use a refrigerator to control the temperature of the milk, resulting in higher quality and better hygiene, and a consistent sales price of $0.11 per liter. This provides an additional income of $671 per month. As the total system cost $35,000, the additional income allows the cooperative to pay for the system within five years. In addition, the cooperative has reduced its labor expenditure by using electric milking machines. The houses near the dairy have all been electrified, and distant houses are able to charge 12-V batteries for domestic lighting. As a further benefit, the cooperative installed a grain mill. The members save the cost of transportation to the city and create a viable business in their own community.

Revolving Credit Fund

El Tinte was able to acquire its micro-hydro power station through a loan from a fund set up by the IADB, and managed by Intermediate Technology Peru (IT Peru). The rotating fund for micro-hydro power plants has funded 15 systems to date in rural Peru. The loans are repaid in five years at 8% interest. The credit amount varies from $10,000 to $50,000. The fund is capitalized with $400,000 at a 1% interest rate over 25 years plus a technical assistance grant. ITDG is currently seeking financing to expand the fund, as demand exceeds the current availability of funds.

Technical Assistance

ITDG has done significant research in micro-hydro power stations. Because of ITDG's high level of technical sophistication, it is able to provide technical assistance in designing and installing the system for the entrepreneurs.

Applications

- **Battery Charging**—Several of the micro-hydro plants have decided to offer battery-charging services to their communities. They usually charge the same or a lesser price for the service than is charged in the nearest electrified town. Local villagers save not only on the service price but also on the substantial time and cost of transportation.

- **Carpentry Workshop**—Many of the micro-hydro plants use the electricity for some sort of workshop (e.g., carpentry or blacksmithing). One carpenter converted a diesel-powered workshop to micro-hydro, powering a circular saw, drill, planer, and a small 600-W generator for lighting.

- **Grain Grinding**—Grain grinding can be accomplished using the motive power of microhydro without converting to electricity.

- **Minigrids**—One of the entrepreneurs provides power to 30 families in the vicinity of his station. This entrepreneur controls the load to his customers through current-limiting fuses that disconnect at 150 W. Income from this enterprise, in addition to battery charging, allows this loan to be repaid within five years.

Teotonio Vilela Foundation (FTV): Franchising PV Power Entrepreneurs in Northeast Brazil

The *Luz do Sol* project provides resources for microentrepreneurs in the remote rural communities of northeastern Brazil, allowing them to start their own solar battery-charging stations. This large FTV program works somewhat like a franchise, with *Luz do Sol* providing a business plan and training for the entrepreneurs, as well as access to financing and equipment. A key benefit of the project will be the creation of a viable commercial energy market where none previously existed, and thus increased income for the families of microentrepreneurs and the potential for more new microenterprises. Through this and other projects, FTV has become one of Brazil's most experienced institutions in the field of renewable energy. FTV is a private, nonprofit foundation established in 1984 in Brazil. FTV's strengths are the staff's technical abilities and expertise in the installation and repair of solar equipment. The institution has also demonstrated an ability to effectively organize low-income rural communities around the issue of renewable energy, while maintaining a business approach to their activities.

The Actors

- **The Inter-American Development Bank**—In mid-1998, FTV requested financing and technical cooperation funding from the IADB for the *Luz do Sol* program in order to introduce and strengthen solar energy service microenterprises in rural, northeastern Brazil. Under this proposal, FTV is specifically prohibited from becoming a financial intermediary; nevertheless, it may act as the conduit between finance and equipment sources and solar energy microentrepreneurs at the community level. FTV arranges financing for microentrepreneurs through the Northeast Bank of Brazil (BNB) and the Golden Genesis Company (GGC). By maintaining the involvement of formal financial intermediaries, FTV reduces its risk and creates favorable conditions for expanded financing in the future.


ITDG Peru / 02618841

Figure 8.6. A battery-charging station brings household lighting and television to the surrounding community members.


ITDG Peru / 02618835

Figure 8.7. A Peruvian carpentry workshop

- **Northeast Bank of Brazil**—BNB has made $10.4 million ($U.S.) available to the *Luz do Sol* project, sourced from a special government line of financing targeted to promote renewable energy. As of May 5, 1998, the rate payable by the microentrepreneur on the BNB line of credit was 11.1% annually, compared to the open-market rate of 19.5%. BNB finances 54% (or $14,850 [$U.S.]) of each microentrepreneur's initial equipment investment. The loan is amortized over 12 years, including an initial grace period of six months during which interest is payable at the end of the third and sixth months.

- **Golden Genesis Company**—FTV has also arranged up to $8.1 million ($U.S.) in financing from the GGC. GGC will finance the remaining $12,650 ($U.S.) of the initial investment and charges the microentrepreneur a fixed rate of 11% per year. GGC pays 2% to BNB as a fee for funds management. GGC financing is amortized over 5.5 years, including an initial grace period of six months during which interest is payable at the end of the third and sixth months.

GGC supplies all of the solar energy equipment. FTV, in turn, installs the battery-charging systems on the property of the microentrepreneur and the electrical fixtures in the homes of users. GGC financed the start-up of the *Luz do Sol* program in 1996–1997, and pays FTV $2,641 ($U.S.) for each system installed. This fee-for-service payment is made in return for FTV's services of identifying and mobilizing communities, establishing microenterprises, providing business and technical training to microentrepreneurs, and monitoring the finances of the program.

The Market

In the three states of Alagoas, Bahia, and Pernambuco, along with the northern portion of Minas Gerais, there are more than 1.1 million properties without electricity. Grid electrical services for these rural areas are unlikely in the near future due to the combination of low industrialization, poverty, dispersed population, and difficult terrain. In this semi-arid region of northeastern Brazil, small farms and businesses are vital to the survival of the majority of families. In Bahia, for example, microenterprises and small businesses generate 45% of the state's gross domestic product and 75% of employment.


SGA Energy Ltd. / PIX07906

Figure 8.8. A battery-charging station

Selecting Communities

Prior to the first installation, FTV carried out significant work identifying and qualifying communities.

A community must meet the following criteria to be considered for the *Luz do Sol* project:

- It must be at least 3 kilometers from the electricity grid and have no electricity supply.
- It must indicate a willingness and ability to financially support an energy service microenterprise. FTV makes this determination through meetings with family leaders from the community.
- A minimum of 50 families must be willing and able to pay a $10 ($U.S.) monthly energy bill in order for the microenterprise to be commercially viable.
- Finally, FTV asks community members to select one person to manage the new enterprise. This person becomes the energy service microentrepreneur.

After screening and prior to establishing the microenterprise, FTV requires at least 50 of the prospective energy customers to pay $10 ($U.S.) each, which is used as a down payment on the energy equipment. A single photovoltaic solar system can provide enough energy for 50 homes and costs $27,500 ($U.S.).

Viability of the Microenterprise

In the *Luz do Sol* program, microenterprises provide battery charging to end users under a fee-for-service model. Each customer pays $10 ($U.S.) per month for as many as four battery charges, giving the entrepreneur a $500 ($U.S.) base monthly income. If a user wishes to have a battery charged more than four times, she must pay an additional $2 ($U.S.) per charge. (Typical expenditures for candles, kerosene, diesel, and batteries are $5 to $8 each month. These costs have been reduced, or in some cases, eliminated by the solar energy service.)

Challenges

A low loan repayment rate by microentrepreneurs was considered the most significant risk to the long-term viability of the *Luz do Sol* project. Current and potential financing agents, including banks and energy suppliers, will not finance the microentrepreneurs if they do not have confidence that the loans will be repaid. So far, the three principal causes for poor repayment have been technical problems with the equipment, shortcomings in the financing model, and the drought that has damaged the rural economy in the region.

The Learning Curve

As of 1998, payments in arrears were 8.3% of the outstanding BNB/GGC portfolio. (As measured by amount of payments overdue divided by the amount of loans outstanding [in the repayment phase].) FTV is considering adjustments to the *Luz do Sol* project in an effort to reduce the amount of payments in arrears to 5.0%. These modifications include:

- Elimination of the grace period to instill the discipline of monthly payments
- Creation of a written policy on sanctions for late payment by microentrepreneurs
- Introduction of a flexible pricing scheme, which will allow the microentrepreneurs to earn higher profits, depending upon the number of users
- Requirement of a greater number of "commitments to use" per community prior to the establishment of a microenterprise, to safeguard against users dropping out.[20]

World Bank: Strengthening Renewable Energy Financial Intermediaries in Sri Lanka

Sri Lanka has developed a wide array of options for end-user finance of solar home systems. The history of the relative success and failure of these mechanisms illustrates the pitfalls of end-user finance and demonstrates that microfinance institutions may well be the most suitable entities to facilitate finance for rural energy services.

Government/Donor Initiative

In Sri Lanka, efforts to provide credit to rural consumers for the purchase of renewable energy technology began in 1989. The government-owned People's Bank, which has an extensive network of branches in rural regions, agreed to target rural consumers, who earn an average of less than $50 per month (for the SHS investment of $200). Approximately 40 loans were extended. The failure of this program to effectively reach poor rural borrowers is believed to lie in general apathy on the part of the branch staff toward small loans and wariness of a new technology. The gulf between the formal financial institution culture and rural needs was too great to permit effective energy dissemination.

The Energy Services Delivery Project

In 1996, a line of credit opened the door for many types of renewable energy project developers and participating credit institutions (PCIs) to provide solar home systems to the rural market. The World Bank's Asia Alternative Energy Unit and the Sri Lankan government funded the Energy Services Delivery Project (ESD) in 1996. The $50–$55 million fund promotes the use of renewable energy in rural areas of Sri Lanka. Ten million is allocated specifically for the dissemination of SHSs by providing financing for the installation of 30,000 systems over five years.

A key component of the venture is financing for consumers. In some cases, the project developer includes an in-house financing unit to assess potential customers, provide loans to eligible buyers, and ensure that a system is in place for collecting repayment. In other cases, the project developer forms a strategic alliance with a PCI to take care of the end-user financing. By opening the door for nongovernmental organizations and private-sector entities to work together, several improvements were gained over the government-bank-led program.

Private-Sector SHS Vendors

Companies that import or sell PV systems are generally strong in technical, marketing, and after-sales support. However, they lack experience providing financing to end users. Solar Power & Light Company, which by 1999 had installed 150 SHSs since June 1997, has its dealers serve as lenders and collection agents for loans to buyers. Another vendor, Alpha Thermal, has installed 100 SHSs in a similar manner. Both companies are finding it difficult to collect repayments from many customers.

One of the difficulties under this model is the varying degree of ability and commitment each dealer feels toward financing.

Energy Service Companies

Under this approach, an SHS is installed in a household, but ownership is retained by the ESCO. The customer pays a monthly fee for the service of electricity. One key to the success of an ESCO is density; the ESCO has to operate in an area where customers are relatively closely located in order to provide adequate service economically.

In Sri Lanka, RESCO, part of the SELCO-USA network, has already accessed the ESD fund to install 1,000 SHSs. A portion of the fund will be used to lend to end users and the other part to operate as an ESCO.

Large Microfinance NGO

Sarvodaya Shramadana Society is one of the largest NGOs in Sri Lanka. It has an extensive rural network and is involved in education, health care, and social, agricultural, financial, and energy-related activities. Sarvodaya Rural Technical Services, the technical division of Sarvodaya, has been involved in SHS since its initial demonstration projects with the Solar Electric Light Fund in 1991.

Sarvodaya already has a rural lending program administered by the Rural Enterprises Program. These organizations are managed by village residents and provide microfinance for agriculture, home improvement, and small business.

Two divisions within Sarvodaya coordinate to implement the SHS project, the Rural Enterprises Program, and the Sarvodaya Rural Technical Services. The Rural Enterprises Program negotiates with the PCI to secure the ESD funding while Sarvodaya Rural Technical Services markets, installs, and services the SHS. Both divisions ensure that repayments are made on time.

Private Finance Companies

The Finance Company (TFC) is a private company that provides funds for consumer goods in rural areas. TFC has an extensive regional network and operates in remote regions. Currently, TFC continues to finance SHS through the local dealers of Solar Power & Light Company. Ironically, the financing of SHS does not have the sanction of TFC's head office; the decision to finance was made by the regional offices. As such, it does not get much publicity. TFC's management has expressed interest in participating in the ESD, possibly with a private SHS vendor in the initial states.

Rural Cooperatives and Banks

The most prominent specialized rural lending organization in Sri Lanka is the Thrift and Credit Cooperative (SANASA). Established in 1906, SANASA boasts more than seven million member households. The organization has three tiers (village cooperatives, regional centers, and the country-level federation). A unique feature of SANASA is the autonomy the village-level cooperatives have in their operations. All the collected savings only get utilized in the village, except for the membership fees for the federation. The federation, in turn, provides the financial management systems, training, and other infrastructure inputs.

One of the latest developments with SANASA is the establishment of the SANASA Development Bank, which is a legitimate entity to access the ESD funds as a PCI. Recently, discussions got under way to develop these areas between SANASA and the administration unit of the ESD.

Commercial Banks

Hatton National Bank (HNB) has started to lend directly to SHS customers, with an SHS vendor supporting the marketing and technical sides of the operation. The vendor, Solar Power & Light Company, has identified many interested SHS customers from an area near an HNB branch. HNB has agreed to lend to 10 customers as part of a pilot program. The potential customers have to be an HNB customer or open an account with the branch. Then, after the bank does the necessary credit evaluation, it will finance 70% of the cost of the SHS for qualified customers.

As part of the ESD project, there is a $100 grant per system provided by the GEF. This amount is to be held in the customer's account at the HNB branch until the loan is repaid, thus giving the bank some financial guarantee while serving as an incentive for the customer to pay the loan. This amount is returned at the end of the three-year period—which acts as a bonus for the customer, as part of it could be used to replace the existing battery. The other option is to discount the capital cost of the SHS by the $100 initially.

Further, HNB secured a guarantee from Solar Power & Light Company, which ensures that the PV module will be repurchased by the company in the event of a customer default.

Lessons from the Sri Lankan Experience

With many experiences still in the early stages, it is difficult to draw concrete conclusions from the Sri Lankan experience. However, some trends stand out. The initial donor-led projects did not focus on establishing a sustainable market or on providing the customer with the sort of attention that was needed to attract a significant number of users. This project depended on a large urban bank to serve as a financial intermediary. As the lending culture of private-finance companies tends to be urban-oriented, such institutions frequently view rural borrowers as offering returns too small to be worth their attention. Moreover, rural people may distrust the "urban formalities."

Private, supplier-led initiatives have had more success because they tend to work more closely with the villagers to provide reliable customer service. Moreover, their pricing policies reflect market rates that foster sustainable market growth. These initiatives, however, often experience difficulty in carrying out the functions of rural finance and cost recovery.

Sarvodaya, a microfinance NGO, has shown good progress by using its strength in both rural finance and technology transfer. Finance schemes are most successful when operated at a "grassroots" level with some central supervision. A "bottom-up" approach empowered the rural community to understand the technology as well as manage the micro-credit programs.

Other rural finance institutions such as TFC, SANASA, and Hutton National Bank show promise as being suitable financial intermediaries for rural energy. The success of these programs will depend largely on the strength of the strategic alliance they are able to form with the project developers, and their united ability to confront several obstacles. These include the following:

- The market is isolated in remote areas of the country.
- The cost of doing business in rural areas is high.
- The cost of SHS is relatively high for the target rural market.
- The urban-based banking system is uncomfortable lending in rural areas and for rural projects.
- PV technology is relatively new to the financial institutions, policy makers, and the market.[21]

REFERENCES

1. "Proceedings: Productive Uses of Electricity in Rural Areas." NRECA Conference: Dhaka, Bangladesh, November 15–19, 1982.

2. Fraser, B. J. "Microcredit: Big Gain on a Small Scale." *Latinamerica Press*. Lima: Latinamerica Press, Vol. 30, No. 6. February 19, 1998; p. 2.

3. Kittleson, D. "Productive Uses of Electricity: Country Experiences." Village Power Conference, Washington, DC, October 1998.

4. Nelson, C., MkNelly, B., Stack, K., and Yanovitch, L. *Village Banking, The State of the Practice*. New York: The Small Enterprise Education and Promotion Network and the United Nations Development Fund for Women, 1996; p. 14.

5. Ibid.

6. Johnson, S., and Rogaly, B. *Microfinance and Poverty Reduction*. Oxford: Oxfam, 1997.

7. Hatch, J. K. *A Manual of Village Banking for Community Leaders and Promoters.* Washington, DC: FINCA, 1989.

8. Johnson, S. and Rogaly, B. *Microfinance and Poverty Reduction*, 1997.

9. Robinson, M. "Saving mobilization and microenterprise finance: the Indonesian experience." In Otero, M., and Rhyne, E. (eds.), *The New World of Microenterprise Finance*. London: Intermediate Technology Publication, 1994, quoted in Johnson, S., and Rogaly, B., *Microfinance and Poverty Reduction*, 1997.

10. Inter-American Development Bank, Internal Document. "Promotion of Rural Renewable Energy Microenterprises in the Northeast Region of Brazil," 1998.

11. Geoghegan, T. and Allen, K. "Interaction Member Profiles 1997–8." Washington, DC: InterAction, 1998.

12. Ibid.

13. Ibid.

14. Lilley, A. "Challenges for Viable RESCOs." Village Power Conference, Washington, DC, October 1998.

15. Naidu and Arora; Pocantico Paper No. 2, Rockefeller Foundation, 1995.

16. Kittleson, D. "Productive Uses of Electricity: Country Experiences." Village Power Conference, Washington DC, October 1998.

17. Ramani, K.V., "Financing Energy Services and Income-Generating Opportunities for the Poor—A Case Study of Project ENSIGN." Workshop on Institutional Co-operation for Solar Energy in the Mekong Riparian Countries, Hanoi, May 1998.

18. IT Peru. "Energía para el Area Rural del Peru." Lima, Peru, 1998.

19. "Rural Electrification Based on Solar Energy." Small Grants Programme of the Global Environment Facility, 1998; John Rogers, personal observations, 1993–99.

20. Inter-American Development Bank, Internal Document." Promotion of Rural Renewable Energy Microenterprises in the Northeast Region of Brazil," 1998.

21. Gunaratne, L. "Funding and Repayment Management of PV System Dissemination in Sri Lanka II." Workshop on Financial Services for Decentralized Solar Energy Applications II, Harare, Zimbabwe, October 1998.

BIBLIOGRAPHY

Microcredit/Microfinance

Bornstein, D. (1996) *The Price of a Dream*. New York: Simon and Schuster.

Christen, R. P. (1997) *Banking Services for the Poor: Managing for Financial Success*. Somerville, MA: ACCION International.

Fraser, B. J. (1998) "Microcredit: Big Gain on a Small Scale." *Latinamerica Press*, Vol. 30 (6). Lima, Peru: Latinamerica Press, February 19.

Goetz, A. M. and Gupta, R. S. (1996) "Who Takes the Credit? Gender, Power, and Control Over Loan Use in Rural Credit Programs in Bangladesh." *World Development*. Vol. 24, No. 1; pp. 45–63.

Hatch, J. K. (1989) *A Manual of Village Banking for Community Leaders and Promoters*. Washington, DC: FINCA.

Holcombe, S. (1995) *Managing to Empower: The Grameen Bank's Experience of Poverty Alleviation*. Dhaka, Bangladesh: University Press Limited.

Holt, S.L. (1994) "The Village Bank Methodology: Performance and Prospects." In Otero, M. and Rhyne, E., (eds.). *The New World of Microenterprise Finance*. London: Intermediate Technology Publications, quoted in Johnson, S. and Rogaly, B. (1997) *Microfinance and Poverty Reduction*. Oxford, UK: Oxfam.

Jain, P. S. (1996) "Managing Credit for the Rural Poor: Lessons from the Grameen Bank." *World Development*. Vol. 24, No. 1; pp. 79–89.

Johnson, S. and Rogaly, B. (1997) *Microfinance and Poverty Reduction*. Oxford, UK: Oxfam.

Levitsky, J. and Prasad, R. N. (1989) "Credit Guarantee Schemes for Small and Medium Enterprises." World Bank Technical Paper No. 58, Industry and Finance Series. Washington, DC: The World Bank.

Nelson, C., MkNelly, B., Stack, K., and Yanovitch, L. (1996) *Village Banking, The State of the Practice*. New York: The Small Enterprise Education and Promotion Network and the United Nations Development Fund for Women.

Olivares, M. (1989) "ACCION International / AITEC: A Methodology for Working with the Informal Sector." Somerville, MA: ACCION International, Discussion Paper #1.

Otero, M. and Rhyne, E. (eds.). (1994) *The New World of Microenterprise Finance*. London, UK: Intermediate Technology Publications.

Ramola, B. and Mahan, V. (1995) "Financial Services for the Rural Poor in India: Policy Issues on Access and Sustainablity." Sustainable Banking with the Poor. Occasional Papers 6. Washington, DC: The World Bank.

Robinson, M. (1994) "Saving Mobilization and Microenterprise Finance: the Indonesian Experienc." In Otero, M. and Rhyne, E. (eds.) *The New World of Microenterprise Finance* (1994); quoted in Johnson, S. and Rogaly, B. (1997) *Microfinance and Poverty Reduction*.

Srinivas, S. (1997) "Self-Employed Women's Association (SEWA) of India: Paving the Way for Women's Economic Progress." Berkeley, CA: *Women and Money*.

Stearns, K. (1991) "The Hidden Beast: Delinquency in Microenterprise Credit Programs." Somerville, MA: ACCION International, Discussion Paper #5.

The SEEP Network. (1995) *Financial Ratio Analysis of Micro-Finance Institutions*. New York: Pact Publications.

UNDP. *MicroStart: A Guide for Planning, Starting and Managing a Microfinance Programme*.

Webster, L. and Fidler, P. (eds.). (1996) *The Informal Sector and Microfinance Institututions in West Africa*. Washington, DC: The World Bank, Regional and Sectoral Studies.

Yaron, J., Bejamin, McDonald, and Piprek, G. (1996) *Rural Finance: Issues, Design, and Best Practices*. Draft. Environmentally Sustainable Development Studies and Monographs Series. Washington, DC: The World Bank.

Microenterprise/Productive Uses

Almeyda, G. (1996) *Money Matters: Reaching Women Microentrepreneurs with Financial Services*. Washington, DC: Inter-Amercian Development Bank.

Aryeetey, E., Baah-Nuakoh, A., Duggleby, T., Hettige, H., and Steel, W. F. (1994) "Supply and Demand for Finance of Small Enterprises in Ghana." World Bank Discussion Papers, No. 251. Africa Technical Department Series. Washington, DC: The World Bank.

Canadian Council for International Cooperation. (1996) "Micro-Enterprise Lessons. Questioning the Panacea: Lessons from a CCIC Learning Circle on Micro-Enterprise Development." Ottawa: Canadian Council for International Cooperation. September 1996. Available on the Web at http: / / www.web.net / ccic-ccci / policy / doc13.html.

Creevey, L. (1996) Changing Women's Lives and Work: An Analysis of the Impacts of Eight Microenterprise Projects." London, UK: Intermediate Technology Publications.

Flowers, L. and Phillips, K. (1995) "Renewable Energy-Based Village Power and Economic Development." *Proceedings: APEC Workshop on Renewable Energy*. Prepared by the Pacific International Center for High Technology Research (PICHTR). September.

Kittleson, D. (1998) "Productive Uses of Electricity: Country Experiences." Village Power Conference, Washington, DC, October.

Kropp, E. (1992) "Financial Systems for the Benefit of the Rural Poor: Appropriate Financial Systems in Suport of Microenterprise Development." *Report of the International Conference on Savings and Credit for Development:* Klarskovgard, Denmark, 28–31 May 1990. New York: United Nations; pp. 155–166.

NRECA. (1982) "Proceedings: Productive Uses of Electricity in Rural Areas." Dhaka, Bangladesh, November 15–19.

Ramani, K.V. (1998) "Financing Energy Services and Income-Generating Opportunities for the Poor—A Case Study of Project ENSIGN." Workshop on Institutional Co-operation for Solar Energy in the Mekong Riparian Countries, Hanoi, May.

USAID. (1995) "Proceedings: Taller Sobre Aplicaciones Productivas de la Energía Eólica y Fotovoltaica." La Paz, Mexico, October 9–13.

Financing Renewable Energy

Annan, R. (1997) "Realities of Sustainable Development." In *Proceedings of Village Power '97,* April 14-15, Arlington, Virginia. Golden, CO: National Renewable Energy Laboratory, pp. 3–5.

Annan, R. H., Malbranche, P., and Hurry, S. (1992) "Strategy for Disseminating / Commercialising Proven Renewable Energy Technologies." *Prospects for Photovoltaics*. New York: Advanced Technology Assessment System. Department of Economics and Social Development, United Nations. Issue 8; pp. 153–159.

Arvidson, A. (1995) "From Candles to Electric Light: Can Poor People Afford Solar Electricity?" *Renewable Energy for Development*. Vol. 8, No. 4. Available on the Web at http: / / www.sei.se / red / red9512d.html.

Cabrall, A., Cosgrove-Davies, M., and Schaeffer, L. (1996) *Best Practices for Photovoltaic Household Electrification Programs: Lessons from Experiences in Selected Countries*. Washington, DC: World Bank Technical Paper No. 324. Asia Technical Department Series.

Cecelski, E. (1998) "Gender and Poverty Challenges in Scaling up Rural Electricity Access." Paper prepared for Village Power '98, Washington, DC.

Clement-Jones, R. and Mercier, J. (1995) *Towards a Renewable Energy Strategy for Sub-Saharan Africa, Phase 1: Photovoltaic Applications*. Paper No. 9. The World Bank Environmentally Sustainable Development Division, Africa Region.

Gregory, J., Silveira, S., Derrick, A., Conley, P., Allinson, C., and Paish, O. (1997) *Financing Renewable Energy Projects: A Guide for Development Workers*. London, UK: Intermediate Technology Publications, and The Stockholm Environment Institute; 157 pp.

Gunaratne, L. (1998) "Funding and Repayment Management of PV System Dissemination in Sri Lanka II." Workshop on Financial Services for Decentralized Solar Energy Applications II, Harare, Zimbabwe.

IT Peru. (1998) "Energía para el Area Rural del Peru." Lima, Peru.

Lilley, A. (1998) "Challenges for Viable RESCOs." Village Power Conference, Washington, DC.

Lovejoy, D. (1992) "Electrification of Rural Areas by Solar Photovoltaics." *Prospects for Photovoltaics*. New York: Advanced Technology Assessment System. Department of Economics and Social Development, United Nations. Issue 8, Autumn; pp. 139–152.

Maldonado, P. and Márquez, M. (1996) "Renewable Energies: An Energy Option for Sustainable Development." *Renewable Energy: Energy, Efficiency and the Environment, World Renewable Energy Congress*, Denver, Colorado, 15–21 June 1996. A.A.M. Sayigh, ed. New York: Pergamon Press; Volume II; pp. 1072–1075.

Northrop, M. F., Riggs, P. W., and Raymond, F. A. (1996) *Selling Solar: Financing Household Solar Energy in the Developing World*. Workshop at the Pocantico Conference Center of the Rockefeller Brothers Fund, October 11–13, 1995. New York: Rockefeller Brothers Fund, Inc., Pocantico Paper No. 2.

Twiddell, J. and Brice, R. (1992) "Strategies for Implementing Renewable Energy." *Energy Policy*, Vol. 20, No. 5, May; pp. 464–477.

Van Nes, W. and Lam, J. (1997) "Final Report on the Biogas Support Programme (Phase I and II); Development through the Market." Kathmandu, Nepal: Biogas Support Programme; June.

Renewable Energy Technology

Barlow, R., McNelis, B., and Derrick, A. (1993) "Solar Pumping: An Introduction and Update on the Technology, Performance, Costs and Economics." New York: World Bank Technical Paper Number 168.

Cowen, W.D., Borchers, M.L., Eberhard, A.A., Morris, G.J., and Purcell, C. de V. (1992) *Remote Area Power Supply Design Manual*. 2 vols. Cape Town, South Africa: Energy for Development Research Center, University of Cape Town.

Cross, B., ed. (1995) *The World Directory of Renewable Energy Suppliers and Services 1995*. London, United Kingdom: James & James Sciences Publishers, Ltd.

Duffie, J. A. and Beckman, W.A. (1991) *Solar Engineering of Thermal Processes*. 2nd ed. New York: John Wiley & Sons, Inc.

Fowler Solar Electric, Inc. (1991) *Battery Book for Your PV Home*. Worthington, Massachusetts.

Gipe, P. (1993) *Wind Power for Home and Business*. White River Junction, VT: Chelsea Green Publishing Company.

Hankins, M. (1993) *Solar Electric Systems for Africa: A Guide for Planning and Installing Solar Electric Systems in Rural Africa*, rev. ed. London, United Kingdom, and Harare, Zimbabwe: Commonwealth Science Council & AGROTEC.

Hankins, M. (1993) *Solar Rural Electrification in the Developing World, Four Country Case Studies: Dominican Republic, Kenya, Sri Lanka, Zimbabwe*. Washington, DC: Solar Electric Light Fund.

Hunter, R. and Elliot, G., eds. (1994) *Wind-Diesel Systems: A Guide to the Technology and its Implementation*. Cambridge, UK: Cambridge University Press.

Jimenez, A. C. (1998) *Optimal Design of Stand-Alone Power Systems for Remote Rural Health Facilities*. Master's Thesis; Fort Collins, CO: Colorado State University.

McNelis, B., Derrick, A., and Starr, M. (1992) *Solar Powered Electricity: A Survey of Photovoltaic Power in Developing Countries*. London: Intermediate Technology Publications.

Nelson, V. (1996) *Wind Energy and Wind Turbines*. Canyon, TX: Alternative Energy Institute, West Texas A&M University.

Sandia National Laboratories. (1995) *Stand Alone Photovoltaic Systems: A Handbook of Recommended Design Practices.* Report # SAND87-7023, Albuquerque, NM: Sandia National Laboratories.

Solar Energy International. (1998) *Photovoltaic Design Manual*. 2nd ed. Carbondale, CO: SEI.

Special Thanks

Doug Barnes, World Bank

Todd Bartholf , Econergy International Corporation

Dipal Barua, Grameen Shakti

Brooks Browne, Environmental Enterprises Assistance Fund

Kathleen Campbell, NREL

Christine Eibs, Singer E&Co

Larry Flowers, NREL

Charlie Gay

Lara Goldmark, Inter-American Development Bank

Lalith Gunaratne

Richard Hansen, Global Transition Consulting

Hank Jacklin, UNDP, Special Unit on Microfinance

Tony Jimenez, NREL

David Kittleson, NRECA Bolivia

Peter Lilienthal, NREL

Art Lilley

Kendall Logan, UNDP, Special Unit on Microfinance

Susan McDade, UNDP, Sustainable Energy and Environment Division (SEED)

Ellen Morris, UNDP, SEED

KV Ramani

Chris Rovero, Winrock International

Jerome Weingart

Ron White, NREL

GLOSSARY

Alternating Current (AC)—Electric current in which the direction of flow oscillates at frequent, regular intervals.

Altitude—The angle between the horizon (a horizontal plane) and the sun, measured in degrees.

Amorphous Silicon—A thin-film photovoltaic (PV) silicon cell having no crystalline structure.

Ampere (amp)—Unit of electric current measuring the flow of electrons per unit of time.

Ampere-Hour (Ah)—The quantity of electrical energy equal to the flow of current of one ampere for one hour.

Angle of Incidence—Angle that references the sun's radiation striking a surface. A "normal" angle of incidence refers to the sun striking a surface at a 90° (or perpendicular) angle.

Annualized Cost—The equivalent annual cost of a project if the expenses are treated as being equal each year. The discounted total of the annualized costs over the project lifetime is equal to the net present cost (NPC) of the project.

Array—A mechanically integrated configuration of modules together with support structure, designed to form a DC power-producing unit.

Azimuth—Angle between true south and the point directly below the location of the sun, measured in degrees.

Battery—Two or more "cells" electrically connected for storing electrical energy.

Battery Capacity—Generally, the total number of ampere-hours that can be withdrawn from a fully charged cell or battery. The energy storage capacity is the ampere-hour capacity multiplied by the battery voltage.

Battery Cell—A galvanic cell for storage of electrical energy. After being discharged, this cell may be restored to a fully charged condition by an electric current.

Battery Cycle Life—The number of cycles, to a specified depth of discharge, that a cell or battery can undergo before failing to meet its specified capacity or efficiency performance criteria.

Battery Self-Discharge—Self-discharge is the loss of otherwise usable chemical energy by spontaneous currents within the cell or battery regardless of its connections to an external circuit.

Battery State of Charge—Percentage of full charge or 100% minus the depth of discharge (see depth of discharge).

Charge Controller—A device that controls the charging rate and / or state of charge for batteries.

Charge Rate—The current applied to a cell or battery to restore its available capacity.

Concentrator—An optical component of a photovoltaic array used to direct and increase the amount of incident sunlight on a solar cell.

Conversion Efficiency (Cell)—The ratio of the electric energy produced by a photovoltaic cell (under full sun conditions) to the energy from incident sunlight on the cell.

Cost of Energy—The cost per unit of energy that, if held constant through the analysis period, would provide the same net present revenue value as the net present cost of the system.

Crystalline Silicon—A type of PV cell made from a single-crystal or polycrystalline slice of silicon.

Current—The flow of electric charge in a conductor between two points having a difference in potential (voltage).

Cut-In Speed—The minimum wind speed at which a particular wind turbine will produce energy.

Cut-Out Speed—The speed at which a particular wind turbine will reduce its power output in order to protect itself from excessive wind speeds. Most small wind turbines do this by tilting out of the wind.

Days of Autonomy—The number of consecutive days a stand-alone system will meet a defined load without energy input.

Deep-Cycle Battery—Type of battery that can be discharged to a large fraction of capacity many times without damaging the battery.

Demand-Side Management—Controlling energy consumption through management of the size or efficiency of the loads, and the time during which they are allowed to operate.

Depth of Discharge (DOD)—The amount of ampere-hours removed from a fully charged cell or battery, expressed as a percentage of rated capacity.

Design Month—The month having the lowest RE energy-production-to-load ratio.

Direct Current (DC)—Electric current flowing in one direction.

Discharge Rate—The current removed over a specific period of time from a cell or battery.

Disconnect—Switch gear used to connect or disconnect components in a stand-alone system.

Duty Cycle—The ratio of active time to total time. Used to describe the operating regime of appliances or loads in stand-alone systems.

Efficiency—The ratio of output power to input power, expressed in percent.

Electric Circuit—A complete path followed by electrons from a power source to a load and back to source.

Electric Current—Magnitude of the flow of electrons.

Electrolyte—A conducting medium in which the flow of electricity takes place by migration of ions. The electrolyte for a lead-acid storage cell is an aqueous solution of sulfuric acid.

Energy Entrepreneur—Owner of a local business that sells energy services or products to the surrounding community.

Energy Services Company (ESCO)—A company that provides energy services on a fee-for-service basis, retaining ownership of some or all of the energy equipment, even if the equipment is housed at the customer's site.

Equalization—The process of mixing the electrolyte in batteries by periodically overcharging the batteries for a short period.

ESCO—See energy services company.

Fixed-Asset Lending—Lending for an asset whose usefulness extends over many business cycles.

Grid—The network of transmission lines, distribution lines, and transformers used in central power systems.

HOMER—A computer model developed at NREL used to derive an optimal configuration for a hybrid renewable energy system based on given resource, load, and cost data.

Hybrid II—A computer model developed at NREL that runs simulations of renewable energy hybrid system performance, used for advanced hybrid system design.

Informal Sector—The segment of a nation's economy that consists of businesses that are not tracked in government statistics, do not pay corporate taxes, and do not have access to formal financial services.

Insolation—The solar radiation incident on an area, usually expressed in watts per square meter (W / m^2).

Inverter—A solid-state device that changes a DC input to an AC output.

IV Curve—The graphical representation of the current versus the voltage of a photovoltaic cell, module, or array as the load is increased from zero voltage to maximum voltage. Typically measured at 1000 watts per square meter (kW / m^2) of solar insolation at a specific cell temperature.

Kilowatt (kW)—One thousand watts.

Kilowatt-Hour (kWh)—One thousand watt-hours.

Life-Cycle Cost—An estimate of the cost of owning and operating a system for the period of its useful life; usually expressed in terms of the present value of all costs incurred over the lifetime of the system.

Load—The amount of electrical power being consumed at any given moment. Also, any device or appliance that is using power.

MFI—See microfinance institution.

Maximum Power Point—The operating point on a PV array IV curve where maximum power is delivered.

Microcredit—The provision of small amounts of credit according to a set of nonconventional banking practices, which may include short loan cycles, frequent payments, social collateral, and a gender focus.

Microenterprise—A small business, possibly home-based, that produces goods or services for cash income.

Microentrepreneur—An individual who operates a microenterprise.

Microenterprise Zone (MEZ)— A center, housing multiple microenterprises, where electricity is provided along with other business support services.

Microfinance Institution (MFI)— An institution that provides financial services that may include microcredit, savings, and insurance to people underserved by formal banking institutions.

Module (Panel)—A predetermined electrical configuration of solar cells laminated into a protected assembly.

NEC—An abbreviation for the National Electric Code, which contains safety guidelines for all types of electrical installations. Article 690 pertains to solar photovoltaic systems.

Net Present Cost (NPC)—The value in the base year (usually the present year) of all expenses associated with a project.

NGO—Nongovernmental organization.

Nominal Voltage—A reference voltage used to describe batteries, modules, or systems (i.e., a 12-volt or 24-volt battery, module or system).

Ohm—A unit of electrical resistance measurement.

Open-Circuit Voltage—The maximum possible voltage across a photovoltaic array.

Orientation—Placement according to the directions north, south, east, and west; azimuth is the measure in degrees from true south.

Panel—See module.

Parallel Connection—The method of interconnecting electricity-producing devices or power-consuming devices, so that the voltage is constant but the current is additive.

Peak Load—The maximum load or electrical power consumption occurring in a period of time.

Peak Sun Hours—The equivalent number of hours per day when solar irradiance averages 1000 W/m^2.

Peak Watt (Wp)—The amount of power a photovoltaic device will produce during peak insolation periods when the cell is faced directly at the sun.

Photovoltaic Cell—A cell that generates electrical energy when solar radiation strikes it.

Photovoltaic System—An installed aggregate of solar array, power conditioning, and other subsystems providing power to a given application.

Power Conditioning—The electrical equipment used to convert power from a photovoltaic array into a form suitable to meet the power supply requirements of more traditional loads. Loosely, a collective term for the inverter, transformer, voltage regulator, meters, switches, and controls.

Power Curve—A graphical representation of a wind turbine's power output as a function of wind speed.

Process Heat—Thermal energy that is used to facilitate an industrial process such as boiling or melting.

Remote Site—Site that is not located near a utility grid.

Renewable Energy (RE)— Energy not produced by fossil fuel or nuclear means; includes energy produced from PV, wind turbines, hydroelectric, and biomass.

Series Connection—A method of interconnecting electricity-producing devices or power-using devices so that the current remains constant and the voltage is additive.

Short-Circuit Current—Current measured when a PV cell (module) is not connected to a load or other resistance.

SHS—"Solar Power System," a small solar PV system often used for domestic or microenterprise purposes.

Single-Crystal Silicon—A material formed from a single silicon crystal.

Solar Cell—Photovoltaic cell.

Solar Thermal Electric—Method of producing electricity from solar energy by concentrating sunlight on a working fluid that changes phase to drive a turbine generator.

Stand-Alone System—A system that operates independently of the utility lines. It may draw supplementary power from the utility but is not capable of providing power to the utility.

State of Charge—The available capacity in a cell or battery expressed as a percentage of rated capacity. For example, if 25 ampere-hours have been removed from a fully charged 100-ampere-hours cell, the new state of charge is 75%.

Surge Capacity—The ability of an inverter or generator to deliver high currents for short periods of time, such as when starting motors.

Temperature Compensation—An allowance made in charge controller set points for changing battery temperatures.

Tilt Angle—Angle of inclination of collector as measured in degrees from the horizontal.

Volt, Voltage (V)—A unit of measurement of the force given to electrons in an electric circuit (electric potential).

Watt, Wattage (W)—Measure of electric power (watts = volts x amps).

Watt-Hour (Wh)—A quantity of electrical energy for which one watt is used for one hour.

Wind Turbine—A device that converts the energy of moving air into electricity.

Working Capital—The liquid assests needed for an enterprise to complete a full business cycle.

ABOUT THE AUTHORS

April Allderdice

April Allderdice is a renewable energy analyst who worked extensively with NREL's Village Power team on projects such as the Village Power database and this guidebook. She is affiliated with Grameen Shakti in Bangladesh, where she worked for two years in residence with the assistance of the Fulbright Fellowship Program and the Echoing Green Foundation. She has a B.A. in physics from Wesleyan University (1994) and is currently pursuing her M.B.A. at Columbia University.

John H. Rogers

John Rogers is a principal of Global Transition Consulting, a joint venture of Enersol Associates, Inc., and SOLUZ, Inc. He is also Vice President of SOLUZ, a U.S.-based PV business and technology development company. Rogers has worked in the field of solar-based rural electrification in Latin America since late 1991, when, during his third year of Peace Corps service in Honduras, he launched a country-wide program in solar electrification patterned on the Enersol model first demonstrated in the Dominican Republic. Rogers has since worked on renewable energy activities in several countries in Latin America, the Caribbean, and elsewhere, under GTC, SOLUZ, Sandia National Laboratories, and DynCorp I&ET. He holds an A.B. from Princeton University and a master’s degree in mechanical engineering from the University of Michigan.

Available to DOE and DOE contractors from:
Office of Scientific and Technical Information (OSTI)
P.O. Box 62
Oak Ridge, TN 37831
Prices available by calling 423-576-8401

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800-553-6847
fax: 703-605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Renewables for Sustainable Village Power

This is the second in a series of rural applications guidebooks that the National Renewable Energy Laboratory (NREL) Village Power Program is commissioning to couple commercial renewable systems with rural applications. The guidebooks are complemented by NREL Village Power Program development activities, international pilot projects, and the visiting professionals program. For more information on the NREL Village Power Program, please visit the Renewables for Sustainable Village Power Web site:

http://www.rsvp.nrel.gov/rsvp/

Produced for the
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

by the **National Renewable Energy Laboratory**,
a DOE national laboratory

with support from the
U.S. Agency for International Development

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste

NREL/BK-500-26188
November 2000