Guides for

Electric Cooperative Development and Rural Electrification

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Table of Contents

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Glossary of Abbreviations

A	Ampere
AH	Amp-hour
AC	Alternating current
ACSR	Aluminum conductor, steel reinforced
A&G	Administrative and general
AWG	American wire gauge
CARES	Central American Rural Electrification Support Program
CCT	Correlated color temperature
CDA	Cooperative Development Authority (Philippines)
CEF	Fronteriza Electric Cooperative (Dominican Republic)*
CFC	National Rural Utilities Cooperative Finance Corporation, also known as NRUCFC (U.S.)
CFL	Compact fluorescent light bulb
CLARITY	Cooperative Law and Regulation Initiative
CONELECTRICAS	National Consortium of Electrification Companies of Costa Rica (Costa Rica)*
DC	Direct current
DISCEL	Electric Distributor of the Hydroelectric Executive Commission of Rio Lempa (El Salvador)*
EBIT	Earnings before interest and taxes
EBITDA	Earnings before interest, taxes, depreciation and amortization.
EEGSA	Electric Company of Guatemala, PLC (Guatemala)*
ESMAP	Energy Sector Management Assistance Program (World Bank)
FUNDAP	Foundation for Economic Development
G&T	Generation and transmission cooperative
GIS	Geographic information system
GPS	Global positioning system
HVD	High voltage disconnection
I	Electrical current, measured in amperes
ICE	Costa Rican Institute of Electricity (Costa Rica)*
IEC	International Electro-technical Commission
INDE	National Institute of Electrification (Guatemala)*
INE	National Institute of Statistics (Bolivia)*
IRR	Internal rate of return
ISPRA	National Institute for Protection and Environmental Research (Italy)
K	Kelvin
klmh	Kilo-lumen hour
kV	Kilovolt
kVA	Kilovolt-ampere
kVAR	Reactive kilovolt-ampere
kW	Kilowatt

kWh	Kilowatt hour
LED	Light-emitting diode
LPG	Liquefied petroleum gas
LVD	Low voltage disconnection
LVR	Low voltage reconnection
MRT	Single wire earth return*
MW	Megawatt
MWh	Megawatt hour
NEA	National Electrification Administration (Philippines)
NESC	National Electrical Safety Code
NGO	Non-governmental organization
NOAA	United States National Oceanic and Atmospheric Administration
NPV	Net present value
NRECA	National Rural Electric Cooperative Association International, Limited
OCDC	Overseas Cooperative Development Council
O&M	Operations and maintenance
PDB	Power development board
PUC	Public utility commission
PUE	Productive use of electricity
PV	Photovoltaic
PWM	Pulse width modulation
R	Electrical resistance
R&D	Research and development
RE	Rural electrification
REA	Rural Electrification Administration, an agency of the Department of Agriculture of the United States, now known as RUS
REB	Rural Electrification Board (Bangladesh)
RFP	Request for proposal
RFQ	Request for quote
ROE	Return on equity
RUS	Rural Utilities Services, an agency of the Department of Agriculture of the United States, previously known as REA
SWER	Single wire earth return
TAG	Technical assistance guide
UL	Underwriters Laboratory
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USTDA	United States Trade and Development Agency
V	Volt
W	Watt
WH	Watt-hour
Wp	Watts peak
WtP	Willingness to pay

*English translation of Spanish abbreviation

Introduction

Sustainable rural electrification is largely built on the pillars of strong enabling laws, inclusive and motivated institutions, and technically sound infrastructure. In a world where approximately 1.6 billion people do not have electricity, these mainstay attributes of a modern necessity are particularly important for sustainable economic development, particularly in rural areas.

The following, *Guides for Electric Cooperative Development and Rural Electrification*, was developed as part of a five-year cooperative agreement between NRECA and the USAID. Its intent is to advance the basic understanding of rural electrification development for policy-makers, donor organizations, and practitioners, specifically in the key facets of building successful rural electrification programs.

The ten modules contained in this publication draw primarily upon the accumulated rural electrification development experience of NRECA, a non-profit, wholly-owned subsidiary of the National Rural Electric Cooperative Association. Starting in 1962, NRECA, largely through funding from USAID, began providing technical assistance in rural electrification program development in Latin America. Since its inception, NRECA has developed some of the most successful rural electrification programs in the world, resulting in reliable electricity service, increased agricultural productivity, millions of new jobs in micro and small enterprises, and higher incomes and quality of life for more than 100 million people in over 42 countries. The majority of NRECA's rural electrification projects have directly benefited from the technical and operational expertise of personnel, directors to linemen, from numerous U.S. electric cooperatives.

Much of NRECA's international technical assistance in rural electrification program design and technical support has included the development of rural electric cooperatives, based on the U.S. model. This publication, likewise, is focused primarily on the recommended approaches to formulating well-functioning cooperative-based rural electrification programs. However, certain modules within this publication are appropriate no matter what electric service utility model is employed. The U.S. experience in the development of a cooperative-based rural electrification program proved highly effective. In 1935, when the rural electric cooperative program was established, approximately ten percent of rural U.S. households had electricity service. Within one generation, over 900 cooperatives were established that provided universal electric service to the rural populations in 47 of the 50 U.S. states. Today, electric cooperatives provide reliable electric power to over 42 million people covering 75% of the U.S. landmass.

The impetus for developing this publication was two-fold. First and foremost, NRECA concluded that the systematic documentation of its institutional knowledge base for achieving success in the field of rural electrification – and the hard-earned lessons from both success and failures over the years – would be a useful undertaking for its own internal benefit. Second, this decision came at a time when NRECA was working increasingly with various international development agencies, governments, nongovernmental development organizations, private entities, and other groups, on a number of new programs in regions of the world where rural electrification was weak and the electric cooperative model largely unknown. It was a natural extension of NRECA's decision to make this publication publicly available to its partners and client countries as new rural electrification development work went forward. These dual purposes, then, formed the principal aims and substance of the NRECA-USAID cooperative agreement.

CONTENTS AND KEY CONCEPTS

These modules were designed for the benefit of the experienced practitioner, as well as donor agency program managers and host government policy-makers. The publication addresses the twin issues of electric cooperative development and rural electrification program design. Enveloping these two issues is the macro-level purpose of providing the reader with the means to create, implement and manage a robust and well-developed program. A comprehensive rural electrification program starts with the policies and provisions of a legislative and institutional framework, and leads to a series of suggested technical and operational tools for accomplishing a properly functioning cooperative electrification program.

The publication leads the reader through ten self-contained modules covering the key elements of electric cooperative institutional development and rural electrification project design and implementation. They include:

1. Legal and Institutional Enabling Systems for Sustainable Electric Cooperative Development

2. Guide for the Creation of Electric Cooperatives

3. Roles and Responsibilities of Electric Cooperative Boards of Directors

4. Business Plan for Electric Cooperatives

5. Methodology for Evaluating Feasibility of Rural Electrification Projects

6. Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects

7. Distribution Line Design and Cost Estimation for Rural Electrification Projects

8. Financial Analysis of Rural Electrification Projects

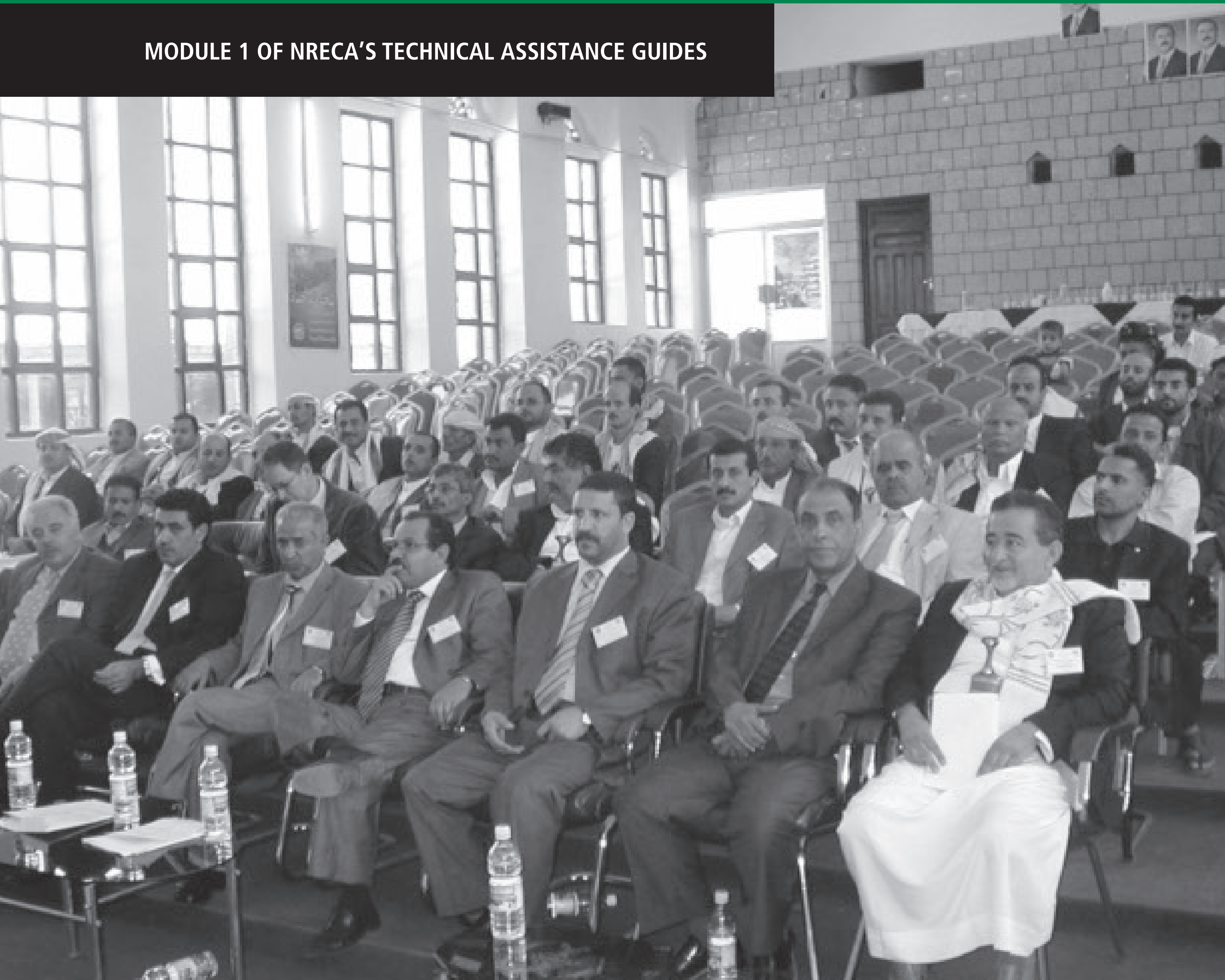
9. Productive Uses of Electricity

10. Design and Implementation Guidelines for Stand-Alone Photovoltaic Systems for Rural Electrification Projects

While each module offers useful information on the selected topics, naturally, various common and important themes intersect throughout the publication. Therefore, we recommend reading this publication in its entirety. Care was taken to ensure that each module presents concepts, terms, and methodologies that could be widely applied. However, we readily acknowledge that these modules are not comprehensively informative. Therefore, further information presenting greater detail on the topics covered, including sample formats for such needs as the legal chartering requirements for electric cooperatives and various technical guidelines, may be obtained by visiting NRECA's website, http://www.nrecainternational.org/News/Publications.htm.

Legal and Institutional Enabling Systems for Sustainable Electric Cooperative Development

MODULE 1 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



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EXECUTIVE SUMMARY

This module reviews the elements of developing a workable legal and institutional enabling framework for electric cooperatives and provides documentary guidelines for complying with the enabling laws and related regulatory components. In addition, it provides details and documentary samples for the organizational structures and internal governing and operating systems of cooperatives, and the agencies formed to enable them.

Electrification experience worldwide has shown that the cooperative business format can work effectively as a scalable and replicable model for bringing electricity to more communities. This has been particularly true in rural areas where approaches using government-owned (para-statal) agencies or for-profit investor-ownership have been ineffective. However, this experience amply demonstrates that the legal and institutional foundation for enabling electric cooperatives is a key determinant of their long-term success or failure.

The legal/institutional architecture for electric cooperative development is complex. It has several tiers, starting with national government policy followed by the implementing laws or decrees, government regulation and oversight. It also includes internal governance and operating rules generally embodied in an organizational charter, bylaws, and written policies of the agencies that the laws create. The same goes for the rules, charter, bylaws, and policies of the cooperatives themselves. To promote good governance, transparency, effective and business-like decision-making, and a healthy degree of public awareness and understanding, these tiers must exhibit a common and consistent set of framework principles from top to bottom.

Adding to the complexity, electric cooperatives function simultaneously under two, and perhaps as many as three, legal systems, sometimes with inconsistent and even competing elements. One legal system corresponds to the cooperative business format, which is a system of private ownership where the customers are the shareholders. In a cooperative, the sole business purpose is to meet the user-owners' service interests, not to obtain a business profit.

The second legal system corresponds to their role as public service utilities that are by nature monopolies and therefore subject to third-party governmental regulation. An electric cooperative is a unique form of public-service utility. As established by cooperative bylaws, consumers elect a Board of Directors to represent and balance the consumers' and the business's interests, creating a certain degree of self-regulation.

A third legal framework is also possible. This framework would entail government establishment of a special rural electrification promotion agency, and this has indeed transpired in all of the world's largest rural electric cooperative programs. If such an agency exists, it can play a purely supportive enabling role in financing, and other needed aspects. However, it may also be endowed with legal powers to incorporate, license, and regulate electric cooperatives, largely displacing the need for the other two enabling systems.

In devising or reforming the enabling environment for electric cooperatives, any combination of the above-mentioned institutional and legal systems is feasible. The legal structure must ensure that cooperatives are established and

Electrification experience worldwide has shown that the cooperative business format can work effectively as a scalable and replicable model for bringing electricity to more communities.

developed with two basic principles in mind. The first is that the legal enabling environment must treat cooperatives in a consistent and logical set of enabling systems that does not allow any of the entities with oversight to be able to use their jurisdictional authority to serve their self-interest. This argues for dividing the oversight responsibilities among two or more entities.

The second principle is that cooperatives must be created as autonomous, private businesses responsible for their own financial survival. This argues for separating the legal incorporation of a cooperative from the laws that create the government's electrification support and oversight entities. Experience relating to this concern also argues for shifting responsibility for such functions as financing, organizational development, and procurement, as a matter of deliberate policy, from the support and oversight entities to the cooperatives over time. This suppresses the tendency of corrupt practices and bureaucratic self-perpetuation on the part of the responsible government authorities.

The laws should also guarantee that everyone who lives within the cooperative's defined territories should have the opportunity to receive electric service.

The recommended legal and institutional system involves the functional allocation of authority and responsibilities in three respects. First, electric cooperatives should derive their legal status as business entities from cooperative law. This law should embody the basic provisions that guarantee their autonomous and democratic nature along with other laws that grant them privileges to operate and compete effectively. This can be accomplished under a separate sub-chapter of an existing cooperative societies law, or by means of a separate electric cooperative law, as was done in the U.S.

Second, the primary responsibility for licensing and operational oversight of electric cooperatives should fall under the electric power sector or public utilities laws. These laws should incorporate special provisions for cooperatives along with regulatory modifications that allow for the special characteristics of non-profit, consumer-owned utilities. The laws should also guarantee that everyone who lives within the cooperative's defined territories should have the opportunity to receive electric service.

Third, the creation of a special rural electrification promotional/development agency, tasked with enabling rural electrification development, is recommended using a special law or executive decree. This agency must have the necessary authority and resource endowment to lead the development of its constituent utilities, but it should not have comprehensive and controlling legal authority over them.

INTRODUCTION

This module of the NRECA Technical Assistance Guides presents the key elements of the legal and regulatory enabling systems required for the development of a self-governing, independently operated, consumer-owned, private electric utility – an electric cooperative. The central themes that underlie appropriately chartered electric cooperatives are a set of governing principles, derived from a governing foundation common to all cooperatively organized businesses. These principles must be imbedded in the legal and regulatory architecture that forms the basis for the charter, bylaws and basic policies of a newly formed electric cooperative.

However, as a public service utility an electric cooperative must also abide by the basic laws and regulatory provisions governing electric distribution entities. Such laws and their technical provisions become embodied in the cooperative's procedures and operating systems. Furthermore, these technical provisions are also mirrored in the legal charters that allow the formation of electric cooperatives.

Indeed, electric cooperatives are substantially different from all other types of electric utilities. They therefore require a specially designed set of enabling systems to be successful. Therefore, as a general recommendation, a wholly unique and self-standing statute should be developed for the legal enablement of electric cooperatives. This national or state statute should allow them to function effectively both as sustainable cooperative businesses and as regulated public utilities.

This module provides details for an enabling law, founding charter, and internal enabling systems for electric cooperatives, based on the experience of electric cooperative development in the United States. The U.S. case was the world's first and largest national system of electric cooperative development. Importantly, it illustrated the essential role of a specialized national rural electrification agency. This organization, originally called the Rural Electrification Administration, served as the institutional linchpin for promulgating comprehensive organizational development, supervision and capacity-building guidelines needed to assure that cooperatives were functioning properly.

Other electric cooperative development examples from several developing countries supplement the lessons of the U.S. experience. These examples illustrate the importance of key elements of the recommended enabling system. Further, because the basic system of laws and regulation in most developing countries differs from that of the U.S., examples show how similarly effective legal and institutional enabling systems can be drawn upto fit the legal system of other countries.

COOPERATIVE EXPERIENCE IN THE ELECTRIC UTILITY SECTOR

Worldwide, there are some 2,000 consumer-owned electric distribution utilities organized as non-profit cooperatives, of which about half are in the U.S. The 930 U.S. electric cooperatives, located in 47 states, serve roughly 17 million consumer owners and a total population of 42 million, covering 75% of the land-area of the country. Other countries where electric cooperatives exist in significant numbers include Argentina, Bangladesh, Bolivia, Brazil, Chile, Costa Rica, India, Italy, the Philippines, and Spain.

Most of these electric cooperatives formed to distribute electricity on the periphery of national grid systems, or as independent utilities powered by local generators in more isolated areas. Most came into being in areas with little or no electricity service. However, in some cases they emerged to replace failed electricity service systems, sometimes private, sometimes government owned, in smaller rural towns, with the idea of expanding service to the surrounding areas.

Electric cooperatives generally exhibit organizational and operational characteristics similar to all electric distribution utilities. They differ, however, in that the cooperative customers own the system that serves them, as illustrated in Figure 1.

Electric utilities are complex businesses. They require highly specialized technical know-how and extensive business development support. Whether the utility is organized as a cooperative or under some other corporate format, it needs professional managers, and well-trained, highly disciplined technical personnel. A typical electric cooperative operates with the following staff:

- The chief executive officer (or General Manager): may supervise a staff of over 100 people, and in the U.S. typically has an advanced educational degree.

- Administrative staff: address the various human resources functions of any large-scale business operation. Qualified administrative staff must include some who can deal with technologically advanced office equipment and administrative systems software, others with complex accounting systems, and still others with the legal expertise to deal with various kinds of contracting needs and regulatory proceedings. In addition, modern-day utilities require specialized communications personnel to conduct sophisticated public

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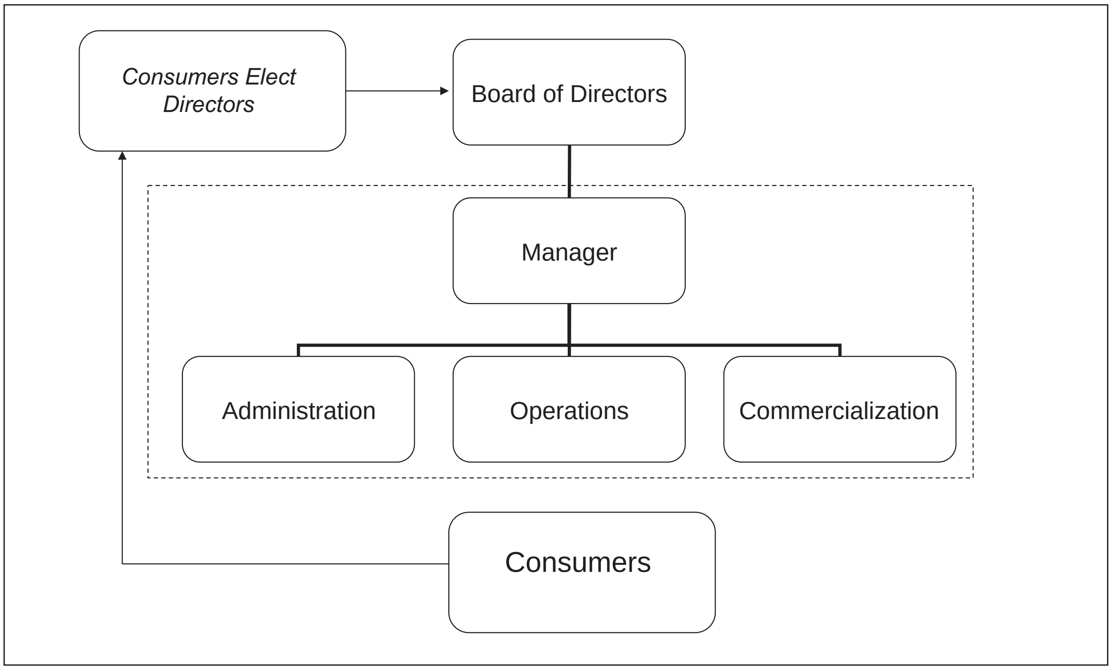
Figure 1. Basic electric cooperative organizational structure



The electric cooperative model is rooted in the ground-breaking cooperative experience of a small group of weavers in the town of Rochdale, England.

information outreach and education programs. Finally, to be successful in today's rapidly evolving electricity utility market, a utility needs an effective public advocacy capability.

- Technical staff: skill sets spanning a diverse technical universe ranging from power-plant operations and maintenance in some cases, to the more common functions of distribution utilities, such as distribution construction planning and maintenance, materials management and warehousing, and operating and maintaining an inventory of vehicles ranging from pick-up trucks to trenching rigs and hydraulic-lift line trucks.

- Commercial staff: in charge of the billing, collections, and customer relations. This demands yet another set of skills and hardware/software capabilities.

Not surprisingly, training is one of the most important elements in the formation of a rural electrification program. From the Director in the boardroom to the lineman on the pole, all cooperative personnel require sufficient and continued training. Experience has shown that in even a setting with the most rudimentary technology, local populations can supply trainable people who over time can develop the skills to cope successfully with all of the above-mentioned functions.

The Cooperative System

The electric cooperative model is rooted in the ground-breaking cooperative experience of a small group of weavers in the town of Rochdale, England. In the mid-19th century these individuals formed the Rochdale Society of Equitable Pioneers and created a basic system of cooperative principles. Over the years since, their early ideas evolved into the following seven principles that are upheld by cooperatives and credit unions worldwide, adopted in September 1995 by the International Cooperative Alliance in Manchester, England:

1. *Voluntary and open membership:* Cooperatives are voluntary organizations, open to all persons able to use their services and willing to accept the responsibilities of membership,

without gender, social, racial, political or religious discrimination.

2. *Democratic member control:* Cooperatives are democratic organizations controlled by their members, who actively participate in setting their policies and making decisions. Men and women serving as elected representatives are accountable to the membership. In primary cooperatives,[1] members have equal voting rights – one member, one vote – and cooperatives at other levels are organized in a democratic manner.

3. *Members' economic participation:* Members contribute equally to, and democratically control, the capital of their cooperative. At least part of that capital is usually the common property of the cooperative. They usually receive limited compensation, if any, on capital subscribed as a condition of membership. Members allocate surpluses for any or all of the following purposes: (a) developing the cooperative, possible setting up reserves, part of which at least would be indivisible; (b) benefiting members in proportion to their transactions with the cooperative; and (c) supporting other activities approved by the membership.

4. *Autonomy and independence:* Cooperatives are autonomous, self-help organizations controlled by their members. If they enter into agreements with other organizations, including governments, or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain their cooperative autonomy.

5. *Education, training and information:* Cooperatives provide education and training for their members, electric representatives, managers and employees so they can contribute effectively to the development of their cooperatives. They inform the general public – particularly young people and opinion leaders – about the nature and benefits of cooperation.

6. *Cooperation among cooperatives:* Cooperatives serve their members most effectively and strengthen the cooperative movement by working together through local, national, regional and international structures.

7. *Concern for community:* While focusing on member needs, cooperatives work for the sustainable development of their communities through policies accepted by their members.

In today's developing countries, the basic laws governing cooperative sectors reflect these principles. As an example of a failed system, the Cooperative Societies Act, established in India in the 1950s, mandated that government own a share of every cooperative – a fundamental violation of Principles #3 and #4 concerning the cooperative membership's autonomous ownership and control. Such distortions may lead to the harmful influence of external political forces on cooperatives, as well as their continuing dependency on government. Equally important, distortions of the seven principles have contributed to a misunderstanding of cooperatives, by some, as virtual extensions of governmental policy and social program administration. In fact, both cooperative members and government must regard and respect cooperatives as independent private businesses to allow a healthy business culture to prosper.[2]

Both cooperative members and government must regard and respect cooperatives as independent private businesses to allow a healthy business culture to prosper.

[1]Cooperative industries tend to develop in two tiers of cooperatives, primary and secondary, where primary cooperatives are formed first, and then in turn develop secondary cooperatives to address common needs. In the electric sector, primary cooperatives are owned by individual electricity consumers at the retail level – they are "distribution cooperatives." Distribution cooperatives may develop and own secondary cooperatives for a wide range of possible purposes, such as providing a common basis to obtain wholesale power supply or capital financing.

[2]In the U.S., the term "cooperative" has gained increased public respect and understanding as a result of the business success of many large cooperative businesses that are well known to the public but were generally not known as cooperatives. In 2004, the 50 largest U.S. chartered cooperatives including the dairy products giant Land O' Lakes, Ace Hardware, and Sunkist Growers grossed $104 billion in revenues on a combined capital asset base of $193 billion. This group included four electric cooperatives.

Even without the problems of faulty law, in some cases cooperative enabling organizations have used their oversight powers to inject political influence in the inner workings of cooperatives. These organizations implement national cooperative laws, serve as the cooperative registrar, and supervise cooperatives on behalf of the government. Their inappropriate use of supervisory power has taken various forms, from political influence over investment decision-making to nepotism and other invasive actions. It is for these reasons, among others, that NRECA recommends the specially defined statutory foundation for the formation, development and oversight of electric cooperatives described in this module.

Electric cooperatives are private businesses, typically chartered under cooperative laws and regulations.

Cooperatives as Public Service Utilities

A variety of business forms exist in the electric utility sector, including government-owned (companies or authorities owned by national or sub-national jurisdictions, such as municipally owned utilities), private profit-seeking investor-owned utilities, and consumer-owned utilities organized as non-profit cooperatives. Note that in some countries, electric cooperatives are operated as outgrowths of agricultural or multi-purpose cooperative enterprises.

Ownership determines for the most part how electric utilities are defined, licensed, and regulated, including how tariff rates are determined. Electric cooperatives are private businesses, typically chartered under cooperative laws and regulations. In some countries, very small-scale community-based service associations have been formed that may be referred to as electric cooperatives. However, such organizations – including user associations of household solar home systems and small service associations that distribute electricity from small isolated generating plants – are not registered under established cooperative laws as private, consumer owned businesses and therefore do not meet the organizational or legal standard of electric cooperatives as discussed in this module. Likewise, in Vietnam and other countries, small grid-connected electric service associations have formed in rural areas as part of governmental decentralization movements, but these are more akin to local governmental entities.

In the United States, electric cooperatives are chartered as private corporations under several statutory forms. In 30 of the 47 states where electric cooperatives exist, they are legally formed under special electric cooperative acts. In the other 17 states, electric co-ops are incorporated under a general cooperative act (11 states), a nonprofit corporation act (3 states), or a business corporation act (3 states). State-level public utility regulatory commissions (PUCs) provide formal regulation. Their mandate includes adjudication of service territories, setting of safety and service standards, and balancing investors and consumers interests with regard to tariff-setting. In keeping with the unique character of cooperatives as consumer-owned utilities, PUCs regulate their tariffs in only 16 of the U.S. states that have electric cooperatives. The Federal Energy Regulatory Commission of the U.S. Government oversees interstate electricity trade, mainly high-voltage transmission systems.

Regulation of electric cooperatives in the U.S. is also indirectly provided by a specialized governmental rural electrification (RE) agency, the Rural Utilities Service (RUS), which was created in 1935.[3] RUS is organized under the United States Department of Agriculture (USDA), and was originally named the Rural Electrification Administration (REA). Its title was later modified to reflect the changing nature of electric cooperatives into multi-purpose businesses, including not only electricity but also telecommunications, natural gas distribution, and other member-determined service and product areas.

[3] REA was first established under an Executive Order by President Franklin Roosevelt and later re-established as a permanent agency by an Act of Congress. Its title was later modified to reflect the changing nature of electric cooperatives into multi-purpose businesses, including not only electricity but also telecommunications, natural gas distribution, and other member-determined service and product areas.

As one of its role, RUS functions as the primary source of financing for rural electric utilities. In addition, RUS provides a comprehensive set of operating standards and procedures for electric cooperatives. Its standards are enforced by the covenants of its loan contracts with cooperatives and other eligible rural utilities. The standards include specific instructions to borrowers in setting tariffs to meet the cost-of-service plus debt service coverage, along with other guidelines for meeting the basic technical and operating standards of electric utilities. The following sections explain how electric cooperatives in the U.S. adhere to the seven cooperative principles.

The following sections explain how electric cooperatives in the U.S. adhere to the seven cooperative principles.

Voluntary and Open Membership

Regulatory provisions require electric cooperatives to offer service to anyone in its state-granted service territory, subject to compliance with the cooperative's membership requirements. This principle receives further support in the borrowing eligibility criteria of the RUS, which that specify a principle of "area coverage." That is, those who borrow from the RUS must demonstrate a commitment to the goal of universal service without discrimination.

Democratic Member Control

Each cooperative member in good standing has the right to vote for democratically elected directors for limited-term seats on a single governing board. This board in turn retains the sole authority over the self-determination and business operations of the cooperative. These directorships typically have three-year terms and represent geographical districts, sometimes along with one or more additional "at-large" seats.

Members' Economic Participation

To receive service, electric cooperative members pay a nominal membership fee and usually a connection fee for the cost of a connection to the electric service line. The investment capital of a cooperative, however, is generally financed by external sources. As a non-profit enterprise, a return on equity is not factored into the tariff. Nevertheless, the cooperative operates with an annual revenue margin to render it eligible for financing and/or compliant with loan covenants. Over time, as the margins which are not applied to system expansion or other purposes approved by the board accumulate, they may be returned to the members in proportion to their energy use, typically on an annual basis. In some of the enabling acts for U.S. electric cooperatives, the sale of additional non-voting capital stock to members may be permitted, but this is rare.

Autonomy and Independence

Electric are cooperatives autonomous legal entities subject to external intervention only in two rarely occurring circumstances: as a result of prescribed administrative procedures or litigation in response to the cooperative's failure to meet its legal obligations, or by a vote of the membership. In the first instance, such intervention may include the RUS replacing an incumbent General Manager as the consequence of an egregious RUS loan covenant default. As an example of the second instance, in states where cooperatives are subject to public utility regulatory oversight, the membership may vote to invite PUC regulation when their confidence in the Board of Directors has eroded.

Education, Training and Information

Training and public education have a high priority in most cooperative laws, and in some countries, surplus revenues may be used only for this purpose. Training was a continuous emphasis of the RUS in the formative years of the US electrification program, and this embedded training as an important feature of electric cooperative administration. Public outreach and member communication take place especially during the developmental stages of a

Regulatory provisions require electric cooperatives to offer service to anyone in its state-granted service territory, subject to compliance with the cooperative's membership requirements.

cooperative. After formation of the cooperative, robust, open, and direct communications and public information sharing continue to lay the groundwork for transparency, good governance, and consumer trust.

Cooperation Among Cooperatives

In the electric utility business, scale is essential, particularly to achieve minimum economic thresholds and to compete effectively. Distribution cooperatives tend to be rural and are therefore at a disadvantage in numbers of consumers, consumption, and consumer density. In the U.S., electric cooperatives have overcome much of this disadvantage by organizing common-service or secondary cooperatives to address many commonly required functions. Secondary cooperatives have formed at the national, regional and State levels to provide financing; marketing services; bulk power supply and marketing services; bulk materials procurement, warehousing and transport; product manufacture including wood poles and transformers; engineering services and R&D; management search and placement services; training; and public advocacy.

In developing countries, electric cooperatives are particularly relevant for effective rural electrification development where governmental and utility privatization models have failed.

Concern for Community

In the U.S., only 10% of farms received electric service in 1935, when the RUS came into being. Electrification was therefore synonymous with economic and social development in disadvantaged rural areas. Member assistance and customer service have likewise become embedded corporate values in the electric cooperative industry. These values are manifested in the provision of direct consumer assistance for house-wiring, agricultural electric and other productive uses marketing and extension assistance, building efficiency assistance, and a growing list of member-demanded non-electric services, including rural development and industrial promotion financing and support. As another illustration of this principle, many U.S. electric co-ops today sponsor foundations that they fund for charitable giving purposes in their communities.[4]

The cooperative principles are in one way or another represented in the enabling laws, internal rules, regulations and/or institutional development patterns of the electric cooperative system in the U.S. For electric cooperatives to achieve long-term stability, these basic founding principles must remain inviolable and be consistently applied, from the broader enabling legislation and institutions down to the individual cooperative's internal governing and organizational systems. At the same time, the cooperative charter should permit and promote adaptability, giving cooperatives the latitude to adjust their constitutions to better address the inevitably changing dynamics of markets, economic patterns, demographic features, technologies, and management/operational best practices. Such adaptive change is generally not possible under the prevailing cooperative law in developing countries.

Key Power Sector Reform Issues and Cooperatives

In developing countries, electric cooperatives are particularly relevant for effective rural electrification development where governmental and utility privatization models have failed. These market failures generally correspond to the underlying question of ownership and motivation.

Government-owned electric utilities have generally failed to provide reliable service coverage with significant market penetration for various reasons. Over-bureaucratization and corrosive politicization, corruption, weak oversight, and lax enforcement of utility policies, and the inability of state-owned enterprises to attract financing as result of poor utility performance are typical reasons for such failures.

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[4]A "Round-Up" program has been adopted by many of these cooperatives as the means of raising the funds – by inviting members to voluntarily allow the cooperative to round-up their monthly bills to the next full dollar amount.

Privatization – the transfer of ownership to profit-seeking investors – has proved problematic for the simple reason that financial returns in rural electric service provision tend to be poor because of the weak underlying economic and demographic conditions of rural areas.[5]

The electric cooperative model is uniquely capable of mobilizing an often overlooked source of private self-interest – the beneficiaries –whose motivation is to obtain electricity service at a cost that is reliable, widely available, and financially and operationally sustainable. Properly constituted cooperatives offer a corporate structure to capture this self-interest in a workable business format. However, the enabling framework for cooperative development is critically important for achieving the intended results. Prior experience with electric cooperative development points to several crucial lessons about important conditions for success.

Sustained Commitment from Government

The impetus for rural electric cooperative development stems from government's fundamental obligation to extend public infrastructure and services to disadvantaged populations. This obligation primarily entails the provision of long-term, low-cost capital for the infrastructure and services. However, it also requires the establishment of an effective administrative infrastructure to set up the enabling framework, including laws, regulations, institutions, and organizations, as well as making these elements work effectively.

These functions are best served by the creation of a competent central agency of the government. This agency should be empowered with a clear mandate and mission to promote rural electrification. It should also have the necessary financial and human resources to help establish cooperatives, guide and supervise their development, and see to the timely inputs of funding, technical assistance and organizational capacity-building for the cooperatives.

Vesting Control with the Cooperative's Membership

Too often, electric cooperatives have been subjected to excessive top-down control by governmental administrative and oversight agencies. Besides the aforementioned extreme case of partial government ownership and board representation mandated by law in India, there are many ways that enabling and supervising authorities of government abuse their powers to undermine the autonomy of electric cooperatives. Specific elements of the enabling legislation for establishing such authorities are critically important. First and foremost, government must limit itself to a facilitative role, with no direct involvement in the constitution or operation of the cooperatives. In particular, the legal chartering provisions for cooperatives, other than for their licensing and oversight, should be separated from the enabling legislation for specialized rural electrification authorities and agencies.

Too often, electric cooperatives have been subjected to excessive top-down control by governmental administrative and oversight agencies.

This was not done in two prominent cases: the Philippines and Bangladesh. Both cases subordinated the electric cooperatives so as to appear an extension of the enabling authority and thus an extension of the government. Placing the chartering authority for the legal establishment of cooperatives under the general law for cooperatives can help prevent this problem. Preferably, the chartering authority should be placed under a separate chapter of the law or an entirely new statute that delineates the particular rights, responsibilities, and institutional features that are unique to non-profit electric cooperatives. In addition, it should place limitations on the enabling agency's supervisory powers.

[5] A compendium of case studies carried out by the World Bank's Energy Sector Management Assistance Program (ESMAP) provides a review of lessons learned in various rural electrification experiences worldwide that point to a number of basic guidelines for successfully addressing the special requirements of sustainable rural electrification development. Several of these case histories involve experience with cooperative approaches and the factors that led to their successes as well as shortcomings. See Douglas F. Barnes, editor, *Meeting the Challenge of Rural Electrification: Strategies for Developing Countries* (Washington, D.C.: Resources for the Future, 2007).

Specific licensing and supervisory controls over the electric cooperatives, as well as the responsibility for developing their capacities to meet its rules and regulations, should reside with the supervising rural electrification agency. The legal, regulatory, and administrative definitions in the founding legislation of both the cooperatives and the supervising agency must stress the independent, private character of electric cooperatives.

Organizations must use a competitive selection system, based on prescribed position descriptions, together with compensation policies that attract strong candidates.

Quality of Leadership and Management

Leaders set the tone for how the business and operating culture of cooperatives evolve. In fact, they fundamentally influence the effectiveness of governance and management functionality in both the enabling agencies and the cooperatives. This is especially true for the leadership of the enabling authority, since it has both formal and informal powers to influence cooperatives on a day-to-day basis. Where leadership is prepared, competent, informed, and property motivated, results have been notably good. Sound operating practices and program execution discipline resonate from leaders to rank-and-file staff, and in turn to the constituent cooperatives. Where leaders do not possess these qualities, results have been poor.

Sustainable success requires emphasis and attention on the employment procedure for management personnel. Organizations must use a competitive selection system, based on prescribed position descriptions, together with compensation policies that attract strong candidates. Governing boards must include provisions to assure a strong democratic system of electing directors, along with the robust participation of cooperative members in their ownership role. This in turn ultimately requires effective membership outreach and education.

Standardization and Scale

The standardization of technical, organizational and procedural facets of electric cooperative development leads to economies of scale. Standardization is critically important given the economic and administrative challenges in rural electrification development. From the standpoint of cost control, standardization based on optimal technical standards (appropriate design for initial cost and durability) maximizes efficient use of scarce investment capital. It also enforces system construction discipline and further economies through program scale-up, allowing for bulk procurement, sharing of materials in disaster recovery, etc.

The same principle applies to institutional aspects of development, including standardization of sub-national laws and regulations, organizational structures, and operating procedures, so as to facilitate a patterned approach to program implementation. This standardization greatly facilitates the formation of cooperatives. It provides training to personnel on a common set of technical and procedural systems and promotes disciplined supervisory functions, including performance monitoring and benchmarking. The enabling legislation definitions, and the subsequent promulgation of the laws implementing regulations and administrative procedures, should emphasize economic and administrative efficiencies.

Assured Access to Markets and Inputs

Because of their economic, demographic, and geographic disadvantages, resulting in lower consumer density and lower revenue-to-investment ratios than urban-based utilities, rural electric cooperatives require special treatment in respect to their access to critical inputs that determine their basic economic viability and competitive welfare. These inputs include, primarily, affordable capital financing and wholesale power supply. They also imply important government responsibilities during the initial stages of electric cooperative development and operations. In the case of financing, long-term, low-cost debt financing must be available over a period of 20-40 years to enable the construction of distribution infrastructure.

Similarly, power supply may require the support of government in long-term financing of power generation facilities, or more likely, in arranging wholesale power contracts at discounted prices. These factors are true for any form of rural electrification development. For cooperatives, the laws, policies and regulatory provisions of the enabling system must assure their access to these vital inputs on terms that enable the cooperatives to meet the electricity needs of their members with reasonably competitive costs.

Government may also be called on to reduce other developmental barriers for cooperatives. This may include providing access to advisory and capacity-building assistance, allowing relief on import duties, supporting the development of related economic and productive infrastructure (such as agriculture extension services to help farmers to adapt to modern energy-dependent production and marketing systems), and providing access to new technologies such as off-grid electricity service systems.

Reducing Dependency on Government

Cooperative members and governing boards must view the cooperative as a private enterprise that is independently responsible for its financial welfare and survival. Given initial help from government in the form of low-cost capital financing, power supply, and capacity-building, cooperatives must ensure that they are geared to meet their financial obligations. Their obligations include recovering the full cost of electricity service. In addition, cooperatives must evaluate and adjust their governance and administrative conduct to comply with the provisions of electric cooperative law, utility licensing, and regulatory compliance.

Cooperatives must also develop, over time, independent capabilities in areas where they initially received government support and subsidy. Experience has shown that extended reliance on government support erodes the autonomy of cooperatives and weakens their performance. Looking to the long term, the enabling systems and policies of government must be fashioned to transparently support, and provide help and incentives for electric cooperatives to build their capacities. These facets of the enabling system enable both parties to work in a common effort to create new strategies and institutions to absorb the functional responsibilities that government agencies initially provide.

Electric Cooperative Case History

The following example of electric cooperative institutional and legal enablement provides helpful points of reference regarding the design of the enabling frameworks for future electric cooperative industries.

The Philippines

A public law, formally enacted in 1969, created the National Electrification Administration (NEA) to take over the rural electrification responsibilities of the government from several pre-existing programs and agencies. The law contained the authorizing elements for the establishment of the NEA and provided the legal authorization for the establishment of electric cooperatives. NEA provided organizational support, financing in the form of long-term loans, coordination with government agencies – specifically with the government's national power company for power supply. NEA also served as regulator with extensive authority over the development and business conduct of the cooperatives. Over approximately a 15-year period, NEA developed 119 electric cooperatives that today serve nearly 80% of the country's rural area, with approximately 8 million consumer-members nationwide. As in the U.S., Filipino electric cooperatives are governed by democratically elected boards and enjoy most of the autonomies of their American counterparts.

In the Philippines, NEA developed 119 electric cooperatives that today serve nearly 80% of the country's rural area, with approximately 8 million consumer-members nationwide.

However, NEA's management style was heavy-handed during an earlier era of its tenure. It engaged directly in the governance and management of the cooperatives, resulting in a certain level of political influence in Board election and composition, as well as favoritism and corruption at the Board and management levels. This interference also led to poor operational and financial discipline.

In recent years, NEA has been restructured and downsized. It is now working to improve those cooperatives that still suffer from the harm created by its past excesses.

The key lesson of this example is that NEA's control over the cooperatives derives directly from the fact that the cooperatives' legal existence is inextricably tied to NEA's enabling legislation. By contrast, cooperatives in the U.S. can "opt out" from RUS oversight by simply repaying the RUS loans. A new electricity law in the Philippines has attempted to remedy this situation by granting electric cooperatives the option of dissolving their ties to NEA by re-registering themselves under the Cooperative Development Authority (CDA), the cooperative supervising agency in the Philippines. Most of the cooperatives have opted not to register with CDA, although the cooperative community is beginning to take strides in formulating new commonly owned agencies that will reduce their dependency on NEA in the future.

ENABLING SUCCESSFUL ELECTRIC COOPERATIVE DEVELOPMENT

Electric Cooperative Law and Regulation

National cooperative laws exist in most developing countries today. Usually, they cover the legal foundation and organizational features of cooperatives, societies, and other types of structured associations. These laws typically have a general section dealing with the basic authorities and responsibilities of the differing cooperative entities, along with separate chapters detailing the specific aspects of different cooperative/ society types (by social and commercial sector). They also include enabling provisions for the government agency responsible for implementing the law. In many cases, the provisions dealing with oversight responsibility also prescribe that the relevant government ministries and functional authorities have responsibility for defining the specific "type" of cooperative.

Each cooperative type is defined within the related sector sections covering cooperatives – transportation, agricultural production and marketing, social services, public infrastructure and services, commerce, etc. In the case of electric cooperatives, authority may be delegated to the ministry or authorized agency concerning electricity, energy, public infrastructure, etc., depending on the prevailing organization of national government. In some countries, a relatively new legal construct such as the Law of Producer Companies in India, subordinated under the national corporation law, offers an alternative legal framework for the incorporation and regulation of member-owned associations, including cooperatives. This legal framework places such cooperative-style companies under the auspices of the administrative and judicial authority of securities and exchange agencies which may not grant the same privileges as cooperatives generally enjoy (e.g. exemption from different types of duties and taxes).

Another legal path entails the promulgation of a separate, stand-alone statute that enables and defines the chartering of electric cooperatives. This includes features that address the general cooperative provisions and the rights and responsibilities of electric cooperatives as public utilities.

Under any system that may be used for the legal chartering of electric cooperatives, regulation generally falls under the supervisory authority of PUCs that are organized in one of two ways:

- under the national electricity ministry (or its equivalent)
- as an independent regulatory body governed by appointed administrators or elected commissioners

In the U.S., the regulatory systems differ from state to state.

Given that electric cooperatives differ in substantial ways from other types of utility corporations, any PUC regulation of cooperatives should accommodate the following special conditions of cooperative enterprises.

Tariff Rate Regulation

Regulators review electricity retail tariffs under an established formula that differs from case to case. However, tariffs are generally determined on the basis of cost plus a prescribed rate of return on the utility's capital assets. The regulator's role is to balance the interest of the consumer to obtain the lowest possible price against the interest of the owner to maximize profit. A consumer-owned electric cooperative exists to provide service at cost, with no allowance for profit. Therefore, in most states in the U.S., PUCs recognize that a cooperative Board has the responsibility to represent the consumers' interest while assuring the cooperative's financial viability, and they do not apply rate regulation. However, the cooperative's charter must provide for the authority of the membership to voluntarily submit to the PUC's rate regulation if they so desire.

Services

Distribution utilities are natural monopolies. PUCs are therefore responsible to the consumers for ensuring that utilities meet the basic standards of service including quality (voltage), reliability (outages), and public safety. Cooperatives are bound by the same oversight requirements. Utility laws and regulations also limit most utilities to the provision of electricity service alone, so they do not take unfair advantage of their monopolistic position in the market.

Electric cooperatives, on the other hand, frequently expand into other services (electrician services, telecommunications, home security, natural gas distribution, and other services and products), subject to the demand and authorization of the membership and Board and as may be permitted by law. There are various reasons why this is justified, including not just the natural authority granted in democratic self-determination as well as the practical efficiency of maximizing a cooperative's administrative infrastructure in rural areas where such services may otherwise be uneconomical.

Service Territories

As noted, the legislation and regulations generally grant electric distribution utilities monopoly status within defined service territories. Territorial disputes between utilities are not uncommon, and cooperatives appeal to this regulatory authority to protect their territorial interest. This may occur, for example, where urban authorities extend their legal jurisdiction into suburban districts, creating conflicts between the municipal public utilities they own and operate and the incumbent electric cooperative. This encroachment can have a severe impact on the economic viability of cooperatives. Where this phenomenon may apply, preferential rule-making to protect the interests of the rural utility is recommended.

Competition

Competition among utilities to serve electricity generally exists only at the wholesale market level. In that arena, regulators at the state and federal level assure open access to power suppliers over privately-owned transmission facilities. At the retail level, electricity service is essentially monopolistic. Nevertheless, in some states electricity laws have been restructured to apply "open access" to the lower voltage networks, as well. This concept potentially applies to cooperatives, as to any other distribution utility but it has not proved significant in the U.S. Power suppliers and marketers are generally not interested in engaging at the retail market, except for larger users.

At the wholesale level, most distribution cooperatives have waived their opportunity to

A consumer-owned electric cooperative exists to provide service at cost, with no allowance for profit.

purchase in competitive markets. They instead opt to execute "all-requirements" contracts with the 66 Generation and Transmission (G&T) cooperatives they collectively own. "All-requirements" clauses grant the G&T the authority to provide 100% of the member distribution cooperatives' power supply needs. Put differently, a member distribution cooperative may obtain power supply only through its G&T. This gives the G&T the required legal and marketing strength to enter with confidence into power purchase agreements with other power producers, with power plant investment financing agreements as direct investors/owners, and for other functional purposes.

Electric cooperatives frequently expand into other services, subject to the demand and authorization of the membership and Board, and as may be permitted by law.

Financing

Cooperatives are generally independent of regulatory considerations regarding financing. However, electric cooperatives have an important provision for repatriating operating surpluses (also known as "capital credits") to the members. The charters, policies, and procedures of a cooperative must provide for this important function – which, among other things, reminds consumers that they are also the owners.

Utility regulatory frameworks are beyond the scope of this module.[6] One significant aspect of regulation, as it concerns cooperatives, is the value of establishing open hearings as a part of how regulatory bodies function. Through this process, PUCs invite the public to attend and comment at hearings and ruling procedures regarding such issues as tariff decisions, siting of utility facilities (e.g., transmission lines), service territory disputes and issues, etc. This empowers a cooperative member, like any utility consumer, with the added protection of having access to a formal adjudicative process to protest tariff rate decisions or other actions by a cooperative Board. For this reason as well, an internal process of periodic meetings for the membership with the Board and management should be encouraged.

[6]See the National Association of Regulatory Utility Commissioners at www.naruc.org.

General Legal/Regulatory Review

To ensure that the seven basic principles of cooperative law are adequately reflected, a systematic review of the prevailing legal framework for cooperatives is recommended. The Overseas Cooperative Development Council (OCDC) in the U.S. has recently put forward an evaluative model to guide the architects of cooperative laws in reforming the enabling frameworks for cooperative development.[7] Their framework, the Cooperative Law and Regulation Initiative (CLARITY), advocates the following seven principles:

1. Protect the democratic character of cooperatives and assure that control is vested solely with their members.

2. View cooperatives as private enterprises individually responsible for their financial welfare and survival.

3. Respect the voluntary nature of cooperative association and membership.

4. Protect and promote equitable sharing of responsibilities and benefits among members.

5. Maintain fair and equitable treatment of cooperative businesses within a larger industry or sector, in terms of incorporation, enforcement of laws and regulations, dispute resolution, and licensing.

6. Grant reasonable support through accommodations and incentives to facilitate cooperatives' access to markets for trade, capital financing, and bulk purchasing power.

7. Provide coherent, efficient and predictable operating environments (policies and regulations, etc.).

[7]*Enabling Cooperative Development: Principles for Legal Reform* (Washington, D.C.: United States Agency for International Development, 2006). This document can be accessed in English, Spanish, and Arabic from http://www.ocdc.coop/clarity/clarity_init.html.

The Electric Cooperative Charter, Bylaws and Governance Provisions

An electric cooperative's internal workings are laid out in three mutually consistent documents, which must generally follow the broader provisions of the basic enabling legislation for cooperatives. These three internal documents are the charter, the bylaws, and the board policies. Among other things, these documents define the system by which each document can be amended under the general authority of the cooperative membership and its Board of Directors.

A cooperative's Charter (also called Articles of Incorporation or Articles of Association) is the basic legal document that establishes how the cooperative is organized and governed. In addition, it may specify the responsibilities of a cooperative's members, responsibilities of the elected Directors, and the general functions of the co-op manager under the overall supervision of the Board. The bylaws follow the general provisions of the charter document. They give greater detail on the internal rules and regulations that govern electric cooperative membership and the duties and functions of the cooperative's Board and management.

The Board must also adopt a set of governance and administrative policies detailing the specific manner in which the cooperative's charter and organizational systems are carried out. Such policies may cover the following areas:

- Corporate governance and Board of Directors
- Employee relations
- Advisors consultants and agents
- Finance and accounting
- Operations
- Tariff rates
- Procurement and contracting
- Member, public, and governmental relations
- Community and economic development
- Electric rules and regulations
- Capital credits

The effective governance and operation of electric cooperatives depends on the clear definition of responsibilities and the effective exercise of these responsibilities between the three basic elements of the cooperative's organization – the members, the Board of Directors, and the cooperative's management. Effective governance relies on several important processes.

The Democratic Process Respecting the Rights of the Owners (Members)

The members provide the governing foundation for the cooperative. They exercise their rights by electing representative directors to the governing board. The Board of Directors, in turn, has the responsibility of supervising the management of the cooperative in keeping with the wishes of the members. They accomplished this by defining the mission and broader strategic purpose of the cooperative, through adopting policies, and by approving business decisions following prescribed procedures. The Board must refrain from entering the realm of management. Its role is to define basic goals and business direction for management and ensure that management applies the policies in accordance with procedure.

The Fiduciary Process and Supervisory Control of Resources and Accountability

The members have the responsibility to provide the capital of the cooperative. It is their elected Board's responsibility to assure that the cooperative's assets are adequately protected while being productively employed in the most effective manner. Management is responsible for presenting plans and actions for the Board's approval, demonstrating the appropriate employment of the cooperative's resources, and implementing approved actions. The Board's critical responsibility is to ensure that its policies,

The Board must also adopt a set of governance and administrative policies detailing the specific manner in which the cooperative's charter and organizational systems are carried out.

and the related operating procedures, are set up in a way that keeps management accountable in fulfilling its responsibilities.

The Decision-making Process and Implementation Oversight

Management, following established procedures, is responsible for developing the business and administrative actions concerning all aspects of the cooperative's business, including system construction and operation, human resources and administrative systems, power supply, regulatory compliance, etc . Where problems arise, management must inform the Board and offer solutions for the Board's consideration. And where problems are sufficiently serious to affect the cooperative's membership in significant ways (e.g. if power supply costs increase beyond expectations, necessitating a tariff rate increase), it is the Board's responsibility to ensure effective communication to the members on the nature of the problem and the steps planned to address it (e.g., reasons for the tariff increase and what the cooperative is doing to protect members from future cost increases). The Board then must fulfill its accountability to the membership to ensure that management undertakes all necessary actions accordingly.

International experience demonstrates that electric cooperative development requires strong guidance and far-reaching vision to promote independent institutional and financial sustainability.

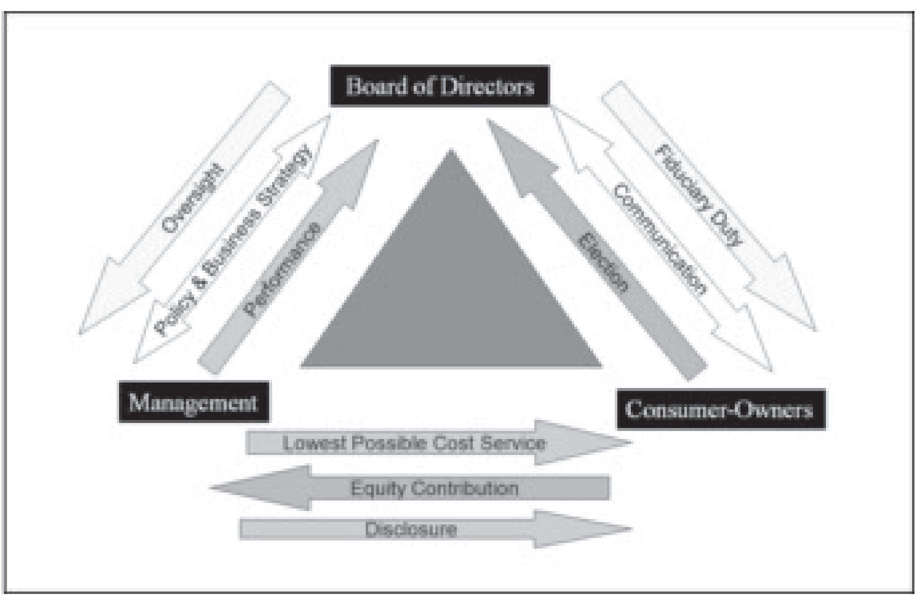
Each of these processes relies fundamentally on good communication among all three elements – the elected Directors, management, and the membership – to maintain transparency and trust on the part of the members, as presented in Figure 2.

BUILDING INSTITUTIONAL CAPACITY FOR A SUSTAINABLE INDUSTRY

International experience demonstrates that electric cooperative development requires strong guidance and far-reaching vision to promote independent institutional and financial sustainability. This responsibility falls initially to the government, through the creation of a mission-driven enabling agency whose sole objective is promoting a sustainable rural electric utility industry. In countries where the cooperative model has been selected for rural electrification, various examples exist for such an agency, starting with the RUS in the U.S.

The central strategy for organizing a national rural electric cooperative development agency

Figure 2. The cooperative governance triangle



is to facilitate the establishment of the primary distribution cooperatives using a reliable, standardized pattern. However, this is not in itself a guarantee of long-term success. There also must be a responsible approach for incrementally transferring functional responsibilities from the rural electrification agency to its constituent cooperative utilities. In a second stage of institutional development, this process involves promoting policies and strategies that require the utilities to formulate secondary cooperatives or other privately organized common-service entities. These entities can then absorb those non-regulatory functional services, and can be administered on a financially self-sustaining basis.

Without a deliberate strategy for accomplishing this second stage, the agency never eliminates the cooperatives' dependency on government. In turn, the lack of independence has at times resulted in a self-perpetuating bureaucracy, increasingly vulnerable to fiscal abuse and politicization.

The Role and Structure of an Effective Supervising Agency

The legal formation of electric cooperatives, as noted, follows the specifications of prevailing law governing cooperative societies. However, the far more complicated problem is devising a suitable enabling structure for shaping electric cooperatives to meet the rigors of regulated public utilities, while shaping both the market environment and the internal workings of electric cooperatives so that they succeed as long-lasting businesses. This challenge represents the purpose and responsibilities of an effective rural electrification supervising agency, which may deal with various kinds of program implementing partners, not solely electric cooperatives.

The enabling agency (referred to as "Agency" in what follows) must be organized and equipped to deal with six key functions and responsibilities.

Financing

Consistent with the lessons learned from past rural electric cooperative experience, reviewed in previous sections, the Agency's most important function is to provide a source of long-term investment capital, in the form of a transparent, needs-driven government subsidy. The recommended package of financing for system construction involves a combination of long-term loans and initial operating grants. The long-term loans include covenants that enforce the operational standards required of successful rural utilities. The initial operating grants ensure that the cooperatives can procure and develop the needed personnel and operating systems (computers, operating equipment and facilities, etc.) during a development period that may last several years.

Licensing

The role of national rural electrification development agencies may include a direct regulatory function through their powers to license service providers.[8] This could involve a two-stage process. First, the Agency may invite proposals from prospective rural utility applicants (including but not necessary limited to cooperatives), awarding the exclusive right to serve to the winning applicant based on defined criteria. After making the award, the formal licensing of service providers would follow, including granting exclusive right to serve in the prescribed service territory.

In the case of cooperatives, member eligibility would follow the requirements established in the prevailing cooperative enabling laws regarding the initial steps in the formation of cooperatives. At the same time, the Agency would establish certifications regarding open and voluntary membership access, establishment of founding committees and Boards, and other provisions including conflict of interest limitations of Directors and senior management personnel.

[8]In the U.S., utility licensing is a function of the PUC.

Planning

The indispensable role of planning, starting with a comprehensive annual plan, is the foundation for assuring program discipline for both the Agency and its constituents. Other plans are required, including long-range service territory plans, which would be based on rigorous demand analysis and financial forecasts, and construction plans, which must be based on project feasibility studies and the disciplined application of appropriate technical designs and construction standards for distribution networks.

Service providers having economically weaker demographic and demand characteristics typically must charge higher tariffs than those with greater consumer density and industrial usage.

Tariff Setting

As part of the loan covenanting, each service provider must be required to furnish tariff plans based on published tariff-setting methodologies, which assure full cost recovery, including debt service, operating costs and power supply. It is vitally important that tariffs be set on an individual basis. That is, service providers having economically weaker demographic and demand characteristics typically must charge higher tariffs than those with greater consumer density and industrial usage. Subsidies to account for economic disparities among utilities are best accomplished through transparent, needs-based discounts for wholesale power supply, facilitated by government power supply authorities.

Load Promotion

Rural areas characterized by lower electricity consumption usually have a greater proportion of residential users than do more urbanized areas. Such communities require that the Agency devote particular effort to its borrower assistance programs. Assistance can include developing and implementing financing products, grant support for local economic development, agricultural extension services, and consumer assistance in the form of productive use equipment promotion, house wiring, and other load promotion assistance in the residential, commercial, and industrial sectors.

Training and Capacity Building

The Agency will have an abiding responsibility to see to the satisfactory organizational and human resource development of its constituent utilities through training their personnel, including technical and operating staff, management staff, and even elected Directors. Such training should be based on the specific technical design, operating standards and procedures that the Agency establishes for system construction and maintenance, administrative systems, governance requirements (e.g., Board member training), and customer services including use promotion.

Organizational Guidelines for the Supervisory Agency

This Agency must have certain key competencies. Moreover, its formulation must be sufficiently comprehensive, but also efficient. In addition, it must have the power to enforce discipline in its constituent utilities (cooperatives) without being intrusive. Finally, it must be geared to a mission that evolves over time.

The underlying organizational principles that are of particular importance for the Agency are the following.

Operational Structures and Systems to Effect Program Efficiency

Excessive bureaucracy hampers institutional performance and goal achievement. The Agency should operate as an enabling, rather than implementing, agency and should be sized to conform to this principle. Without owning, operating or maintaining the infrastructure, the Agency has the chief responsibility of developing effective service provider utilities. The utilities must meet economic, technical, and operational standards that assure effective use of resources and good business practices, including the principle of cost recovery.

Community Welfare and Fairness Considerations

The Agency's mission is to serve the economic and social welfare needs of its client rural populations. Therefore, the involvement of beneficiary communities in the design, development, and control of the Agency's client organizations is critically important. The Agency should also seek the adoption and maintenance of national and local policies to assure fair treatment of rural consumers, as well as the cooperatives' access to economic resources, organizational development assistance, and appropriate technologies. The goal is in maximization of rural energy services penetration and the fostering of local independent control.

Good Governance

The Agency should be autonomous, to render it free from the political control of either the legislature or a supervising ministry of government. The enabling legal statute should be worded so as to guarantee such autonomy. The Agency should itself be designed to operate as a model of good governance, from its governing Board down to its operating elements and functional responsibilities. To achieve this aim, the Agency's enabling legislation and internal regulations and guidelines should clearly delineate provisions requiring that all decision-making be based on business-like policies and procedures, similar to the way a private enterprise would conduct its business. Finally, these business culture norms should be transferred to the constituent utilities through the promulgation of licensing, organizational, and operating standards that are uniformly and rigorously applied by the Agency in fulfilling its supportive and supervisory roles.

Transparency

A key Agency goal is to win the confidence of its funding sponsors. It can accomplish this by demonstrating effective controls over funds management and procurement, with strong, built-in organizational oversight.

Competencies

The Agency's good performance requires people who are competent and diligent in performing their duties. This starts with proper recruiting systems, compensation that rewards performance, and training in its operating policies and procedures.

The Agency should be autonomous, to render it free from the political control of either the legislature or a supervising ministry of government.

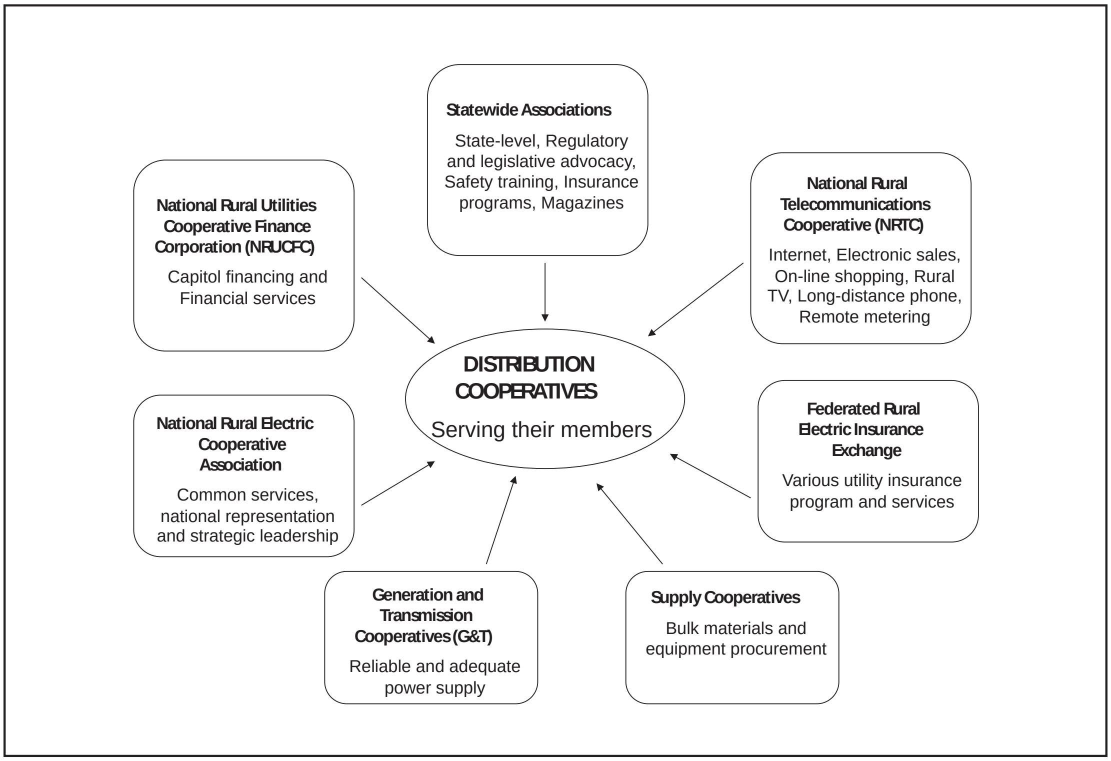
Promoting Independent Electric Cooperative Industries

The general area of cooperative long-term institutional development at an industry-wide level is beyond the scope of this module, especially concerning the form, legal determination, and organizational design of secondary cooperatives to support an expanding and maturing group of electric distribution cooperatives. In the U.S., a wide range of related support agencies are today engaged in various common services activities for their members. Figure 3 illustrates some of the more important entities in the present-day U.S. electric cooperative industry.

Two of the nationally organized agencies that are predominantly responsible for supporting the primary interests of the U.S. cooperative industry are the following:

- National Rural Electric Cooperative Association www.nreca.coop. Formed in 1942 as a national association of electric cooperatives, the National Rural Electric Cooperative Association provides services to both primary and secondary electric cooperative entities in areas of policy development and public advocacy, training and conferences, employee benefits administration, technical research and development, and other functions. Comparable organizations now also exist in Brazil, Argentina, Costa Rica, and the Philippines.

Figure 3. The U.S. electric cooperative industry



The legislation and the legal charters for enabling electric cooperatives must be consistent with the prevailing laws and business-culture norms of each country.

- National Rural Utilities Cooperative Finance Corporation (CFC) www.nrucfc.coop. CFC is a cooperatively organized financial lending and services corporation with approximately US$20 billion in assets. CFC's capital comes from participating member cooperatives, including both distribution cooperatives and secondary cooperatives, through the subscription of long-term capital certificates. These certificates are then leveraged by issuing bonds and other debt instruments in U.S. and internationally. RUS gave initial impetus for CFC by requiring all RUS borrowers to obtain a portion of their construction work plan financing requirements from other lending sources. It then entered into a mortgage-sharing arrangement with CFC. Some 50 electric cooperatives in the Philippines have recently formed a similar corporation.

Information on the organizational structures and services of these common-service cooperatives may be obtained by accessing the indicated websites.

CONCLUSION

The recommendations presented in this module offer general guidance in preparing the institutional and legal foundation that promotes successful cooperative electrification development. The legislation and the legal charters for enabling electric cooperatives must be consistent with the prevailing laws and business-culture norms of each country. The principles mentioned apply not only where electric cooperatives are planned as a new undertaking, but also where reforms of existing electric cooperative systems and laws may be needed to correct problems.

In either instance, getting the basics right is critical to the long-term success of rural electrification under a cooperative format. No amount of funding, technical assistance, or training, will correct problems that are rooted in flawed institutional, legal, and regulatory foundations.

In recapitulating the fundamentals for success, Figure 4 presents the basic institutional/legal set-up for a well-functioning electric cooperative industry.

The three most important points to understand about the relationships in Figure 4 are these.

Autonomy

Electric cooperatives must be autonomous. Cooperatives that remain dependent on government for their basic sustenance over extended periods are often those who become vulnerable to bureaucratic control, politicization, and corrupt practices. Rarely have cooperatives prospered under the long-term influence of an interfering bureaucracy.

Electric cooperative autonomy depends essentially on their democratic nature, along with effective governance that should flow from democratic rule. Nevertheless, autonomy is also fundamentally tied to the institutions and laws under which cooperatives are legally constituted. The legal incorporation of cooperatives must not be accomplished under the same law that creates and empowers the governmental oversight agency that is responsible for supervising them. That creates an environment ripe for conflicting interests. Instead, adopt a separate statute for the formation of electric cooperatives, which allocates regulatory and oversight powers to separate government authorities, according to functional requirements.

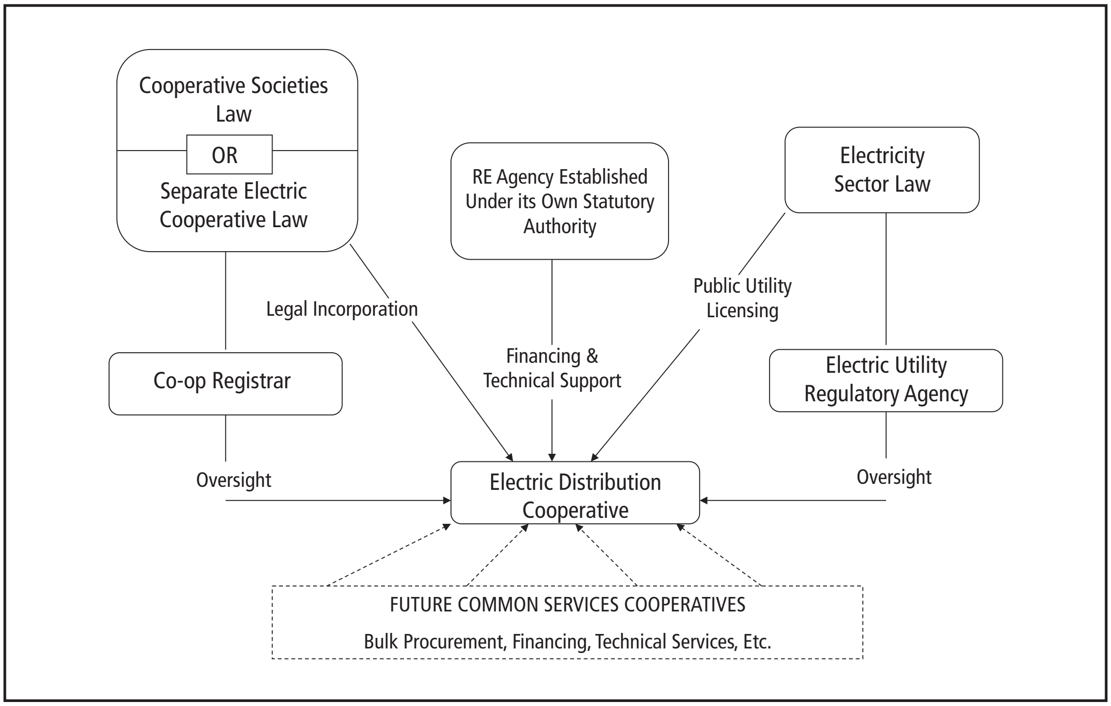
Private Enterprise

Electric cooperatives must be viewed and treated as private business enterprises. This principle must be implicit throughout the laws, charters, policies and procedures comprising the enabling framework for electric cooperatives. Cooperatives require the powers and responsibilities to operate, become financed, charge prices, and be regulated as businesses responsible for their own survival.

In addition, laws and regulations governing electric cooperatives must assure that they are treated equitably and fairly in the context of their larger sector industries, especially with respect to tariff setting and taxation. Over time,

Laws and regulations governing electric cooperatives must assure that they are treated equitably and fairly in the context of their larger sector industries, especially with respect to tariff setting and taxation.

Figure 4. Electric cooperative enabling framework



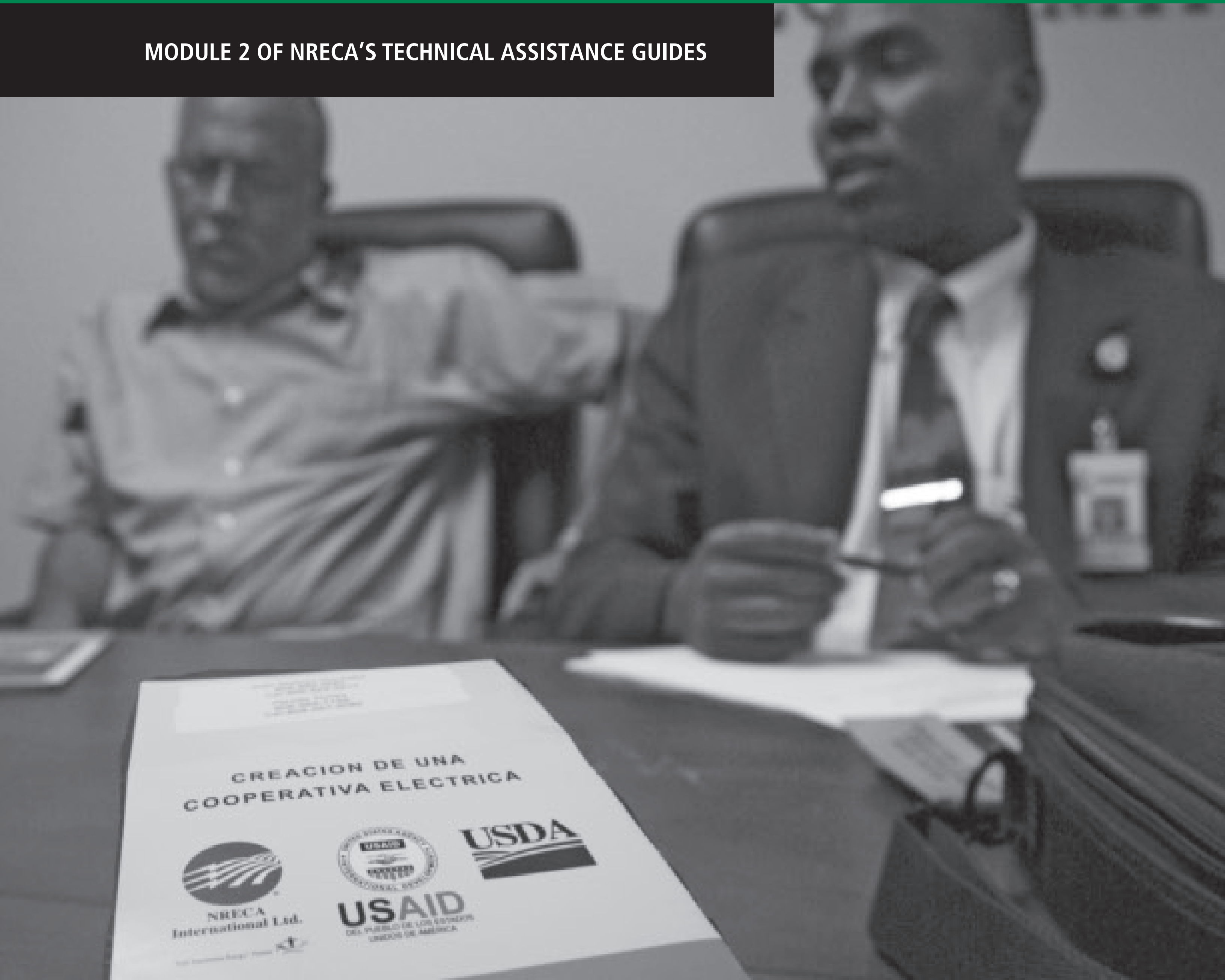
cooperatives should be led to formulate long-term business and organizational strategies to compete successfully for market resources in a fully evolved electricity sector, among other needs. These marketing resources include investment capital, power supply, and even market share. Rural utilities have effectively accomplished this through aggregation strategies, such as secondary cooperatives, common-service enterprises collectively owned as associations of individual electric cooperatives.

Guidance

Electric cooperative development programs require guidance, but not a heavy hand. Most of the more successful rural electric cooperative programs have benefited from long-term support provided by external sources. In most instances, support has come from a facilitative agency endowed with the government's authority and resources to help the cooperatives achieve organizational, operational, and financial success thresholds. Such an agency must be truly facilitative. Through its financing agreements with cooperatives, the agency can exert the needed influence to ensure that cooperatives adopt and follow healthy operational patterns and procedures. Otherwise, such an authority is exercising limited oversight. These functions are best handled by independent and impartial regulatory agencies with no self-interest in the operational decisions made by the entities subject to their jurisdiction.

Guide for the Creation of Electric Cooperatives

MODULE 2 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



2

EXECUTIVE SUMMARY

This module serves as a reference for developing countries that are embarking on the creation of a new electric cooperative. It presents a step-by-step process to form a cooperative, which is often the most appropriate solution to a lack of electricity in rural areas.

The process described here builds on the experience obtained from organizing numerous cooperatives. Using this module to guide the formation process promotes greater efficiency and promises a higher probability of success. The methodology presented, though consistent in its principles, is sufficiently flexible to adapt to on-the-ground realities faced by project proponents in various countries.

Summarized below are the 18 steps required to organize an electric cooperative, based on NRECA's cumulative experience and the methodology outlined in the USDA report, *How to Organize a Cooperative*.[1]

1. Conduct a leadership meeting to discuss the need for a cooperative.

2. Meet with people who have expressed interest in forming an electric cooperative. Vote to determine if process should continue. If affirmative, select a Provisional Committee.

3. Survey potential members to determine interest in the creation of an electric cooperative.

4. Conduct a General Meeting to discuss the results of the survey. Vote to decide whether or not to proceed.

5. If the decision is to proceed, choose a Steering Committee.

6. Contact government and regulatory organizations, e.g. the Ministry of Energy.

7. Conduct a feasibility study.

8. Hold a General Meeting to discuss the results of the feasibility study. Take a secret vote to decide whether to proceed.

9. Develop a business plan and financial analysis.

10. Hold a General Meeting to discuss the results of the financial analysis and the business plan. Vote on whether to proceed.

11. Prepare the necessary legal documentation and initiate the incorporation process.

12. Carry out a member registration campaign.

13. Conduct a Founding Assembly with all the potential charter members to approve the Bylaws and choose a Board of Directors.

14. Conduct Board Meetings to elect officers and assign responsibilities to implement the business plan.

15. Implement the necessary legal steps, e.g. incorporation, service territory concession,

[1]Galen Rapp and Gerald Ely, How to Organize a Cooperative, USDA Cooperative Information Report 7 (Washington, D.C.: USDA, 1996), available online at http://www.rurdev.usda.gov/rbs/pub/cir7/cir7rpt.htm#General%20Rules%20for%20Success.

construction authorizations or transfer of existing electrical infrastructure, and tariff approval.

16. Prepare a capitalization plan and loan applications.

17. Prepare to start operations by hiring a General Manager and acquiring the necessary infrastructure, tools, and equipment.

18. Commence operations

INTRODUCTION

An estimated 1.6 billion people around the world live without access to electricity. Where electricity does exist, poor quality of service is often the norm. In response to this reality, communities face three options:

1. *Business-as-usual:* A community may resign itself to a life of subsistence and underdevelopment due to the lack of modern reliable energy services.

2. *Wait and see:* A community may appeal to the national or private electric utility to help them electrify, and wait to see how the request is prioritized.

3. *Communal organization:* Community members may organize themselves to create and operate their own electric distribution organization, such as an electric cooperative.

A cooperative is often formed when people realize they can do something to help themselves. Creating a cooperative, however, should follow certain steps to ensure that it is the best solution to bring electricity to a community.

This module guides those individuals and communities who have decided to create a cooperative to bring electricity to a community and/or to manage their electrical system.

The cooperative organizational model, where agreements are made between people to solve problems and improve living conditions, has been in existence since the dawn of recorded history. For example, the Egyptians, Sumerians, and the early native peoples of present-day Latin America developed cooperative-style organizational structures. The cooperative approach has demonstrated inherent value to humanity, inspiring solidarity in response to natural disasters and in efforts to solve social problems afflicting humanity.

Formally organized cooperatives emerged following the Industrial Revolution, which had a severe impact on the working and lower-income classes. In 1844, the first recorded modern-day cooperative was formed in Rochdale, England, as a reaction to the social depression of the time.[2] In this first cooperative, a group of entrepreneurs banded together in an effort to open a storefront of their own. At the time, the advent of the modern machine was quickly forcing skilled laborers into poverty. However, this group was able to pool together skills and capital, to persevere collectively where they had failed individually. Through this process, they established the Rochdale Principles. These principles serve as the basis for the seven cooperative principles embodied in the International Co-operative Alliance's *Statement on the Co-operative Identity*.[3]

Electric cooperatives have existed in various countries throughout the world for decades. However, the electric cooperative model of the United States has proven to be the most successful model. In 1935, less than 10% of rural Americans in the United States had access to electricity. At the time, private electric companies did not consider the rural areas financially attractive. Several communities therefore began to form electric cooperatives to service their need for

[2] "Rochdale Principles of Co-operation 1937 - Section 1." International Cooperative Alliance. 21 Jan. 2009 http://www.ica.coop/coop/1937-01.html.

[3] "Statement on the Co-operative Identity." International Cooperative Alliance. 21 Jan. 2009 http://www.ica.coop/coop/principles.html.

electricity. Steadily, one cooperative after another was formed. By 1970, 35 years later, an impressive 99% of rural communities in the United States had been electrified using the cooperative model.

The cooperatives formed a service organization in 1942 called the National Rural Electrical Cooperative Association. Its purpose was "to overcome World War II shortages of electric construction materials, to obtain insurance coverage for newly constructed rural electric cooperatives, and to mitigate wholesale power problems."[4] Today there are more than 900 electric cooperatives within the United States. NRECA's work began in 1962. Since the program's inception, international electrification projects developed by NRECA have benefited more than 100 million people globally.

Electricity is a basic and necessary ingredient for sustainable development. Most modern conveniences require electricity to operate. Often, access to electric service is taken for granted in urban areas, where it is a prerequisite for life's daily activities. In rural areas, however, especially in communities in developing countries, the arrival of electricity is a major event. The day that "light arrives" to an area is a memorable day that many people later remember with great satisfaction. For many, it is remembered as the moment when the community became part of "civilization" and truly "joined the world."

When electricity arrives in a community, the social, commercial, and entrepreneurial dynamics transform, providing new opportunities for businesses to grow, for people to begin new enterprises, and for education, health, and cultural life to advance.

This brief summary alone should justify efforts by rural areas to obtain modern energy services. However, history has demonstrated that rural areas are typically not financially attractive to many commercial electric companies, primarily because the return on investment is likely to be lower than required for profit-oriented entities.

When the need for modern energy services becomes evident, many communities begin to lobby the electric company (state-owned or private) to obtain electrical service in their area. Like most people, they seek quality service at affordable prices. When it becomes apparent that the state or private electric company will not deliver electricity to them, communities turn to alternatives. A community may decide to form their own electric company, following these principles:

- The company is owned by the members it serves.
- Each member is entitled to a vote.
- The surplus revenue (margins) at the end of each year is redistributed to members according to the amount of electricity each consumed during the year.

This is the electric cooperative model.

Since the program's inception, international electrification projects developed by NRECA have benefited more than 100 million people globally.

Definitions

The following definitions will enhance understanding of the subject matter in this module.

- *Cooperative:* "A cooperative is an independent association of people who voluntarily come together in order to face their common social and cultural needs and their economic aspirations by means of a jointly owned and democratically controlled company."[5]
- *Provisional Committee:* Group of people named from among those who consider it worth finding out whether sufficient interest

[4]"History of Electric Co-ops." National Rural Electric Cooperative Association. 21 Jan. 2009 http://www.nreca.org/.

[5]"Information on Co-operatives." International Cooperative Alliance. 21 Jan. 2009 http://www.ica.coop/coop/index.html.

exists among potential members to form a cooperative. They verify initial interest and position the project to become an official organization.

- *Steering Committee:* Group of people elected by those interested in forming a cooperative. They are responsible for steering the process to its formal conclusion including celebrating the Founding Assembly.

Electric cooperatives have proven to be productive and effective models for rural electrification.

- *Founding Assembly:* The meeting during which the founding members officially form the cooperative.

- *Board of Directors:* A group of people chosen by the members to govern the cooperative.

- *General Manager:* A person contracted by the Board of Directors to direct the daily operations of the cooperative.

- *Member:* A person who has fulfilled all requirements stipulated in the cooperative's bylaws regarding membership.

Purpose

In the face of the challenges of life in developing countries, there are leaders who step forward with a strong desire to find solutions. In many cases, these individuals have either visited or become aware of places where problems similar to theirs have been solved. With this knowledge, they begin to consider possibilities to achieve similar results within their spheres of influence. This module provides instruction for such forward-looking leaders on the necessary steps to create an electric cooperative, using specific methods of investigation, organization, planning, and execution.

This module can direct the formation of any size of electric cooperative, from one organized by a neighborhood group to bring electricity to their street or locality, to one of much greater scope. The methodology easily adapts to the scale of the cooperative effort.

Global Perspective

The module was designed for use in developing countries throughout the world. Cultural and socioeconomic reality, however, varies greatly from country to country, and from project to project. With this in mind, project proponents must be sensitive to the national, regional, or local context where the cooperative is to be formed and adapt their approach accordingly.

BACKGROUND

The creation of an electric cooperative often occurs in response to a conventional electric company's refusal to extend service to specific areas, typically rural areas. In general, the return on investment in less populated regions outside urban areas is insufficient to attract conventional, for-profit utilities. Electric cooperatives, however, have proven to be productive and effective models for rural electrification. Numerous developing countries[6] have demonstrated the economic feasibility of the cooperative model for rural electrification. It continues to be an effective model for rural and peri-urban communities to gain access to modern, affordable energy services, provided by an institution responsive to community needs.

General Cooperative Concepts

A number of commonly understood cooperative concepts apply in all cultures and countries. These include values, principles, social purpose, and three distinguishing characteristics of the cooperative model.

Values

Cooperatives are based on the values of mutual aid, responsibility, democracy, equality, fairness, and solidarity. Members believe in the ethical values

[6]Douglas F. Barnes, *The Challenge of Rural Electrification: Strategies for Developing Countries*. (Washington, DC: Resources For The Future Press, 2007).

of honesty, transparency, social responsibility, and care for others.

Principles

Cooperative principles are guidelines for implementation of the values. These principles were approved by the International Cooperative Alliance as part of the Statement on Cooperative Identity,[7] and are in still in effect today. The seven principles are as follows:

1. Voluntary and open membership

2. Democratic member control

3. Member economic participation

4. Autonomy and independence

5. Education, training and information

6. Cooperation among cooperatives

7. Concern for community

Cooperatives' Social Purpose

The social purpose of a cooperative is to improve the quality of life of its members, to integrate them into the economic development processes of the country, and to advance the electric services provided in an area towards best-practices standards.

Distinguishing Characteristics of the Cooperative Model

Three fundamental characteristics distinguish the cooperative model from a commercial or for-profit corporate model.

1. *Financial Participation*. Typically, investors in a commercial company contribute capital in order to make a profit on their investment through dividends and share price appreciation. If the company prospers, the investor gains through dividend increases and higher share prices. In a cooperative, the "dividend" is a member's proportional share of the surplus revenue (margins) remaining at year end (based on each member's energy consumption).

2. *Individual Contribution - Required Investment.* In a commercial company, investors buy shares according to their financial capacity and discretion. In a cooperative, each member is typically required to contribute some capital initially (e.g. a registration fee), and additional capital is provided in the cost paid per kilowatt-hour consumed. Cooperative financial policies and conditions dictate the capital investment required by members to maintain economic viability.

3. *Management Decisions*. In a commercial entity, only majority shareholders may play a role in the administration of the company. In a cooperative, all members have some part in determining policies and in directing the general course of business. In some cases, delegates elected by the membership provide guidance to the cooperative, and in other cases, membership meetings provide opportunities for members to directly influence cooperative management.

Cooperative financial policies and conditions dictate the capital investment required by members to maintain economic viability.

In an electric cooperative, all users are co-owners of the company, except for users who choose not to become members and simply remain as consumers.

Electric Cooperatives Compared to Investor-owned and Publicly Owned Utilities in the United States

In the U.S., the cooperative institutional model has proven to be an effective and successful approach to delivering electric utility services. When administered professionally, cooperatives can offer similar services and tariffs to those of private investor-owned and/or government-

[7] Ibid.

operated electric utilities. However, electric cooperatives typically comprise significantly lower numbers of users and much less income per mile of electric line. In fact, income per mile of private and/or government-operated electric line can be more than seven times larger than that of cooperatives, as shown in Table 1.[8]

NRECA's Experience in the Creation of Cooperatives

NRECA was created to apply the expertise of America's rural electric cooperative community to developing practical and lasting solutions for rural electrification throughout the world. The mission of this program is to provide global leadership for rural electrification efforts in developing countries in helping to bring electricity and economic and social development to rural areas around the world through adaptation of the highly successful U.S. rural electric cooperative system.

Through the years, NRECA personnel have provided support in the creation of numerous electric cooperatives. NRECA has helped form electric cooperatives in numerous countries, including Nicaragua, Costa Rica, El Salvador, the Philippines, Bolivia, Bangladesh, and the Dominican Republic.

[8]Adapted from NRECA webpage,: http://www.nreca.org/AboutUs/Co-op101/CooperativeFacts.htm

Table 1. Comparisons between electric cooperatives, investor-owned utilities, and public utilities in the US

	Investor-Owned	Publicly Owned	Cooperatives	Total
Number of Organizations	220	2,000	930	3,150
Number of Total Customers	102 m	20 m	17 m	140 m
Size (median number of customers)	400,000	2,000	12,500	
Customers, % of total	73%	15%	12%	
Revenues, % of total	76%	14%	10%	
kWh sales, % of total	74%	16%	10%	

Sales (billions kilowatt hours)	Investor-Owned	Publicly Owned	Cooperatives	Total
Residential	937	202	213	1,360
Commercial	1,017	207	75	1,285
Industrial	725	153	83	954
Other	4	3	0	7
Total	2,683	564	372	3,619

	Investor-Owned	Publicly Owned	Cooperatives	Total
Miles of Distribution Line	50%	7%	43%	
Customers per mile of line (density)	35	47	7	34
Revenue per mile of line	$62,665	$86,302	$10,565	$60,827
Distribution plant per Customer	$2,229	$2,309	$2,845	$2,362
Assets (billions)	$700	$200	$100	$1,000
Equity (billions)	$220	$55	$31	$306

Note: "Investor-Owned" includes data for investor-owned affiliates engaged in competitive retail markets where appropriate.
Source: 2005 EIA, RUS Data, CFC
National Rural Electric Cooperative Association Strategic Analysis • Last Updated: February 2008

Through many years of experience assisting with numerous projects in many countries, NRECA learned that the needs and motivation of people everywhere are similar, when it comes to electricity service and improving lives. In particular, people everywhere are willing to act in their own self-interest as communities to obtain electricity. NRECA's success comes from tapping this motivation; from its basic belief that electrification makes a unique and comprehensive contribution to development; and from the attitude of practicality, flexibility, and innovativeness in its approach to designing and implementing projects.

One of NRECA's most successful electric cooperative programs is in Bangladesh.

Bangladesh Project

As a result of an agreement signed in October 1976 with the Power Development Board (PDB) of Bangladesh, NRECA conducted a comprehensive feasibility and organizational study for the implementation of a nationwide rural electrification program. The study resulted in the establishment of the Rural Electrification Board (REB) that has developed from a small government body to coordinate early electrification efforts to one of the most successful electrification programs in all of Asia.

With NRECA's continued assistance over the past 30 years, REB has designed and organized 70 rural electric cooperatives serving 7.3 million connections, or 45 million people, and covering almost the entire country. Over 373 substations and 206,000 km of lines have been energized. NRECA provided assistance to REB in design, construction, and utility operations. NRECA recently provided additional technical assistance to develop small, 10 MW power plants as well as an institutional renewable energy strategy to complement the conventional electrification program.

METHODOLOGY FOR CREATING A COOPERATIVE

The methodology to create an electric cooperative developed through experience gained from organizing numerous cooperatives. The 18 steps described here enable the process to flow more efficiently and achieve a higher probability of success. This approach is based on a combination of NRECA's international experience, and information presented in *How to Organize to Cooperative*.[9] The methodology is flexible enough to adapt to various situations in different countries.

The 18 steps for organizing a cooperative are as follows:

1. Conduct a leadership meeting to discuss the need for a cooperative.

2. Meet with people who have expressed interest in forming an electric cooperative. Vote to determine if process should continue. If affirmative, select a Provisional Committee.

3. Survey potential members to determine interest in the creation of an electric cooperative.

4. Conduct a General Meeting to discuss the results of the survey. Vote to decide whether or not to proceed.

5. If the decision is to proceed, choose a Steering Committee.

6. Contact government and regulatory organizations, e.g. the Ministry of Energy.

7. Conduct a feasibility study.

8. Hold a General Meeting to discuss the results of the feasibility study. Take a secret vote to decide whether to proceed.

With NRECA's continued assistance over the past 30 years, REB has designed and organized 70 rural electric cooperatives serving 7.3 million connections, or 45 million people.

[9] Opt.

9. Develop a business plan and financial analysis.

10. Hold a General Meeting to discuss the results of the financial analysis and the business plan. Vote on whether to proceed.

11. Prepare the necessary legal documentation and initiate the incorporation process.

12. Carry out a member registration campaign.

13. Conduct a Founding Assembly with all the potential charter members to approve the Bylaws and choose a Board of Directors.

14. Conduct Board Meetings to elect officers and assign responsibilities to implement the business plan.

15. Implement the necessary legal steps, e.g. incorporation, service territory concession, construction authorizations or transfer of existing electrical infrastructure, and tariff approval.

16. Prepare a capitalization plan and loan applications.

17. Prepare to start operations by hiring a General Manager and acquiring the necessary infrastructure, tools, and equipment.

18. Commence operations.

The process of starting an electric cooperative begins when individuals decide to address the issue of electric service in their area.

The following sections of this module elaborate on these steps, providing details, suggestions, and recommendations to assist in implementation.

STEP 1: Leadership Meeting

The process of starting an electric cooperative begins when individuals decide to address the issue of electric service in their area. It may be that there is no electricity service at all. Possibly the electric service is of poor quality. Or perhaps the community wants a change, regardless of how reliable the service is. For example, they may want to obtain a more competitive tariff or a more community-oriented service. In any instance, the first step is to convene a meeting of interested parties.

During this meeting, the project leaders or proponents discuss whether the formation of an electric cooperative is an appropriate solution to their problem. If they agree that this approach has a high probability of success, or at least that the concept is worth further exploration, the next step is to determine who else is interested.

STEP 2: Project Scoping

During the next step, interested parties may meet several times. If interest is sufficient, the community may nominate a Provisional Committee to determine the scope of the initial project, or they may immediately appoint or elect a Steering Committee with responsibilities for a specific series of functions.

If a Provisional Committee is formed, its main task is to seek out interested parties and collect basic market data and information. Such data will be needed to present a convincing project to the corresponding regulatory agencies in the electric sector and the cooperative sector, as the case may require in the legal context of each country. The data might include:

- Area population and main cities
- Territory to be covered
- What productive uses of energy are present in the area?
- What are the community's first impressions of the project? How do people respond when they first hear about the project?
- What energy source will be used? Will it be connected to the grid or be an isolated system?
- How will financing be acquired for construction of the electric system?

- Is there an existing system available for acquisition? What deficiencies exist, and how will system rehabilitation be financed?

The following factors should also be considered to promote the probability of success in forming a new cooperative:

- *Lines of communication:* Establish reliable lines of communication to permit project proponents access to one another at all times of the day, and throughout the year.

- *Population stability:* Ascertain whether seasonal laborers or nomadic peoples represent a significant percentage of the proposed project population.

- *Company-owned housing:* Investigate the existence of company-owned housing or lodging in agricultural or industrial centers, where inhabitants have access to housing only through labor contracts (and do not have title to property). If a significant portion of the project area population lives under these conditions, it could affect the feasibility of the proposed electric cooperative.

- *Divisions among population groups:* Explore divisions that exist within the community that could be detrimental to cooperation. Become aware of racial, religious, political, and social class discrimination and biases, and how they affect life in the community.

Project proponents should consider these and other social concerns that could affect the feasibility of an electric cooperative in a target region. In addition, cooperative developers should ascertain whether they will be able to fully satisfy both the short-term and the long-term demand for electricity in the communities.

STEP 3: Survey Potential Members

Next, ascertain that interest among potential members of the affected community is sufficient to proceed with the project. To gauge interest, use a survey. Survey responses provide proponents with quantitative information regarding the level of interest in the community and indicate whether there is sufficient support to set the project in motion. The survey should also reveal the community's willingness to make capital contributions and pay the tariffs necessary to maintain the cooperative's financial viability.

In some countries, government organizations may require proof of interest in the project within the affected community. There may be a legal stipulation dictating a minimum number of members required to form an electrical cooperative. In the Dominican Republic, for example, the law requires a minimum of 200 members to form any public service cooperative. A survey can be an appropriate preliminary tool to address such requirements.

The survey form should be unbiased and worded to elicit honest answers. Pollsters should be thoroughly educated about the project, so they can respond to questions and address reactions within the community.[10]

Project proponents should consider these and other social concerns that could affect the feasibility of an electric cooperative in a target region.

STEP 4: General Meeting: Survey Results

Hold a meeting with the interested parties to discuss the survey results. Following discussion, attendees should vote to decide whether or not they should proceed with the project or not. If the group agrees to move ahead, they should select a Steering Committee.

STEP 5: Steering Committee

Whereas the Provisional Committee has the limited responsibility of verifying initial interest and positioning the project to become an official organization, the Steering Committee has a greater scope of functions. It assumes management of

[10] For more information on how to conduct surveys, refer to NRECA's Module 6: *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*

the entire project until the Founding Assembly takes place. Therefore, the Steering Committee should include representatives from all the major population centers and key groups in the target area. This facilitates information flow in two directions: from the committee to the responsible government organizations and from the committee to potential members and other interested parties. Broad representation on the Steering Committee will greatly bolster the success of the process, assist in properly informing prospective members prior to the Founding Assembly, and assure that all legal requirements are duly met.

The Steering Committee is responsible for a number of functions that may be outside of the technical ability of its individual members. For this reason, the committee will often seek technical assistance to complete the necessary tasks, such as preparing a willingness-to-pay study.

Technical assistance might come from a variety of sources and will depend upon the availability of experts in the country. The committee sometimes can rely on qualified personnel in a reputable government agency. Other sources for technical assistance are international donor organizations and non-governmental aid organizations.

The Steering Committee is responsible for the following:

- Obtain a template to formulate the cooperative's bylaws from the appropriate government agency, or alternative source.
- Discuss the scope of the cooperative's bylaws.
- Manage and coordinate a course on cooperatives for the founding members.
- Carry out a survey to determine the level of interest for an electric cooperative within the community.
- Determine approximate project costs, employing technical assistance as needed.
- Establish a quota for initial capital requirements needed to form the cooperative.
- Establish the quota for the number of applications (i.e. enlisted members) required to form the cooperative.
- Formulate documentation to recruit members and raise capital.
- Raise capital contributions.
- Educate the public about the project. The global project may include both the formation of an electric cooperative and an electrification project, in which case the education campaign should cover both.
- Hold periodic information and coordination meetings.
- Prepare a report for the Founding Assembly.
- If the project includes acquiring an existing system, obtain necessary legal documents that indicate that the sale of the existing electric system can take place.
- Create debate rules for the Assembly.
- Carry out the logistics, preparations, and arrangements to hold the Founding Assembly meeting.
- Convene and run the Founding Assembly.

STEP 6: Initiate Contact with Government and Regulatory Agencies

The Steering Committee should initiate contact with appropriate government organizations and regulatory bodies to obtain a clear understanding of the legal and regulatory aspects related to creating and operating an electric cooperative. The committee must identify requirements, timelines, and actions necessary to comply with existing laws and regulations, and determine whether new legislation may be required for the establishment of the cooperative.

National Legislation

In some countries, the creation of an electric cooperative may require new national legislation. If electricity in the country is provided solely by a national utility, legislation is required to authorize privatization of parts of the national utility by electric cooperatives. Note also that while most democratic countries have created laws facilitating the organization of cooperatives, not all authorize the organization of electric cooperatives.

Consideration of national legislation, therefore, requires a review of existing laws to determine whether privatization (including electric cooperatives) is possible, and whether the existing cooperative laws need revision to clearly identify electric cooperatives as a type of cooperative. Discussions and negotiations must be conducted at the national level to assure that proper laws are in place for the proposed electric cooperative to be formed. For more information on this process, review Module 1 *Legal and Institutional Enabling Systems for Sustainable Electric Cooperative Development*, and the publications, "CLARITY - Enabling Cooperative Development – Principles for Legal Reform" and "Creating CLARITY: Assessment, Analysis and Outreach for Cooperative Legal Reform - CLARITY II" publications, available through the Cooperative Development Program's Cooperative Law and Regulation Initiative,[11] funded by USAID.

Regulatory Agencies

National governments normally rely on agencies to regulate energy activities. In some countries, regulatory agencies exist for both the electric sector and the cooperative sector. In some cases, the Steering Committee must submit the proposed project to the agency that oversees the cooperative sector and have an official promoter assigned to the project. The promoter is responsible for helping the founders comply with all the legal requirements to form a cooperative. Even in that instance, a cooperative promoter may never have overseen the creation of an electric cooperative. Therefore, electric cooperative organizers must also approach the pertinent electric sector entities to learn about standards, regulations, and legal requirements that apply to electric cooperatives.

Relevant standards and regulations may include the following:

- Requirements for "Articles of Incorporation" or "Articles of Association"
- How to legally define a service territory
- How to obtain a concession to distribute electricity (or a concession for generation and authorizations for transmission, if the project includes those components)
- How to value existing electric assets within the proposed territory
- How to legally transfer existing assets to the electric cooperative
- Operating license (or charter) requirements to authorize an electric cooperative
- Employment laws for cooperatives
- Construction standards
- Public safety
- Environmental protection
- Power line right-of-way and clearances laws and standards (e.g. removal of trees and buildings) for the construction and operation of the electric grid

Discussions and negotiations must be conducted at the national level to assure that proper laws are in place for the proposed electric cooperative to be formed.

[11]Please visit www.ocdc.coop/clarity/default.html for more information

- Rules on respecting and protecting indigenous peoples
- Regulations concerning private property easements
- Regulations concerning national parks and preserves (if applicable to the proposed project)
- Tariff regulations
- Reporting requirements
- Others

Research and quantitative analysis will help convince prospective electric cooperative members, government officials, and funding sources that the electric cooperative should be created.

Some type of government oversight is necessary to provide consistent financial, regulatory, and management controls for electric cooperatives. Major lenders, such as the World Bank, require oversight by an authorized government agency. The agency should have direct ties to the government, while at the same time retain limited autonomy so as not to be politically influenced. An oversight agency specifically for electric cooperatives is the best solution. National laws should be examined to determine whether such an agency exists or can be created. The creation of such an institution is beyond the scope of this module, and its existence is not a prerequisite to the formation of an electric cooperative.

Other Discussion Items

Other important areas for discussion with government and regulatory entities include:

- Source of wholesale power (either self-generation or power purchased from the grid)
- Employment laws for cooperatives
- Tax laws for cooperatives
- Fees and dues applicable to cooperatives
- Laws concerning employment unions and the effect on cooperatives
- Identification and evaluation of environmental laws
- Monitoring and evaluation needs

STEP 7: Conduct a Feasibility Study

A feasibility study (formal project assessment) then helps to determine whether the project should be implemented. Research and quantitative analysis will help convince prospective electric cooperative members, government officials, and funding sources that the electric cooperative should be created.

A feasibility study should include:

- Market research
- Willingness-to-pay analysis
- Project characteristics
- Proposed system map
- Projected load flow studies
- Project cost estimates
- Initial financial projections

Market research is a key aspect of feasibility analysis. To determine whether the market is large enough to justify the project costs, the Steering Committee and the project advisors should assemble pertinent information relating to the target region, including total population, target area economics, and the area residents' ability and willingness to pay for the proposed electric service. Information sources may include government organizations (e.g. department of statistics, department of commerce, agricultural extension, etc.), universities, electric utilities, community organizations, development agencies, commercial organizations, and consulting companies. When vital information cannot be obtained from other sources or does not exist, the

Steering Committee must contract with experts to perform surveys and studies.

The Steering Committee should consult with experts to develop preliminary project design characteristics, including a proposed system map and projected load flow studies. Engineering advisors should prepare estimates of project construction costs. If the proposed cooperative is acquiring an existing system, the costs should include the acquisition price as well as the cost of any improvements or rehabilitation required to provide satisfactory service. Financial advisors should prepare initial financial projections for the project, including expenditures related to establishing offices and acquiring the equipment and materials needed to operate the cooperative.

STEP 8: General Meeting to Discuss Feasibility Study Results

After completing the feasibility study, project organizers should present the results to the potential members for consideration. Following discussion, conduct a secret vote to determine whether the majority supports continuing the process to organize the cooperative. Those who are in favor of proceeding should then register as members. By signing an application form, the candidate for membership makes a commitment to pay the registration fees, contribute capital to the cooperative, and to fulfill member duties and requirements specified in the cooperative bylaws.

At the General Meeting, be sure to inform potential members about the way registration fees and capital contributions will be handled and how payments will be refunded in case the process fails, or if a member withdraws.

STEP 9: Business Plan and Financial Analysis

A business plan is a critical element in the cooperative development process, serving two functions. First, it helps ensure that all aspects of the project have been considered. Second, it serves as a vehicle to inform prospective members and lending agencies about the project. A clearly written business plan forces project supporters to examine all facets of the business, to obtain the best information and reduce the potential for misunderstandings. Lenders always require a written business plan and financial analysis. It demonstrates that the project sponsors have adequately evaluated the revenues, costs, and risks of the project.

The business plan expands on information obtained for the feasibility study and includes the following components:

- Project history and overview
- Market analysis: Estimated electricity sales by customer class (numbers of consumers and kWh sale projections); willingness-to-pay study results
- Power supply: Power source and transmission supply; plan for initial and future power requirements; pricing and reliability of supplier(s)
- System design: Diagrams of electrical system; system design and costs; energy loss projections; schedules for major additions and associated costs
- Management plan: Description of project ownership and organization; governance and legal representations; list of staff positions with wages/salaries
- Operational plan: The guiding operational philosophies, including how the electric lines will be maintained, bills prepared and collected, engineering and planning, etc.
- Marketing plan: How the entity will engage with consumers, government, and local community; retail pricing targets; growth targets

- Regulatory approval requirements: Identification of governmental authorities that exert regulatory oversight; approval process steps

- Financial and economic analysis: Financial modeling for at least ten years; documentation of major assumptions; sensitivity analysis to demonstrate risks and returns

- Project implementation schedules

The Steering Committee presents the results of the financial analysis, attendees deliberate the business plan, and the community members vote on whether or not to proceed with the project.

Financial analysis is an essential feature in the business plan. It establishes the financial viability of the project. Lenders require this analysis as part of the financial due diligence process to evaluate the cooperative's ability to repay debt.

Though ultimate responsibility for the business plan belongs to the Steering Committee, it is advisable to hire a reputable expert to prepare the business plan and financial analysis. The Steering Committee must be integrally involved in validating assumptions used and providing feedback as the plans take shape. Complete technical guides on these subjects are available from NRECA.[12]

STEP 10: General Meeting to Discuss Results of the Business Plan and Financial Analysis

The meeting to review the business plan and financial analysis is one of the most important meetings in the process of creating a cooperative. The Steering Committee presents the results of the financial analysis, attendees deliberate the business plan, and the community members vote on whether or not to proceed with the project. Often this decision will affect the life of thousands of people and will involve an investment equivalent to millions of dollars. Given the implications of this decision, it is worth reiterating the importance of having a solid business plan and financial analysis. The results are only as good as the data and assumptions used. Deciding to proceed only to discover later that the decision was based on erroneously optimistic projections can be very costly.

STEP 11: Prepare Legal Documentation

The Steering Committee must complete the paperwork for legal requirements with respect to incorporation and operation. In the first category are all the documents needed to found an electric cooperative and obtain its legal identity. Depending on local laws, documents required to incorporate a cooperative can include:

- Articles of Incorporation

- Bylaws

- The membership roster

- An official record of the Founding Assembly meeting

Articles of Incorporation (also known as Articles of Association) are primary rules governing management of the cooperative. They identify the name, address, nature, and term (duration) of the business, as well as its purposes and powers. Articles of Incorporation are typically only a few pages long.

Bylaws contain directives governing the internal management of the cooperative. They specify how the cooperative will conduct business, the membership requirements, the rights and responsibilities of members, how to call and conduct membership meetings, how directors and officers are elected or removed, how net margins will be distributed, the process for redeeming equity, etc. This document is often more lengthy than the Articles of Incorporation. The cooperative's owner-members have authority to approve the bylaws. (Some countries require extensive Articles of Incorporation, which may include much of what would normally be in bylaws.)

[12] See Module 4: *Business Plan for Electric Cooperatives*, and Module 8: *Financial Analysis of Rural Electrification Projects.*

The Steering Committee must determine what the national requirements are and prepare the Articles of Incorporation, bylaws, and other documents accordingly. The required documentation must then be submitted to the corresponding government agency. Upon approval, the cooperative receives the pertinent decree or certificate of legal identity.

The cooperative must obtain not only the legal right to exist but also the legal right to operate, which indicates the second category of legal requirements associated with a new electric cooperative. Without the right to operate, the cooperative may exist legally, but it will not be able to distribute any electricity. The preference is to obtain its own exclusive concession – a defined service area within which it has the sole right to distribute electricity.

Important legal documents associated with the relationship between the cooperative and its members include the membership application form, which serves as the legal basis for a person to become a member of the cooperative, and capital contribution certificates.

Other legal documentation governs the relationship of the cooperative with other institutions. One of the most vital of those legal documents is a purchase contract for energy, commonly called a power purchase agreement, signed with one or more entities from whom the cooperative buys electricity.

STEP 12: Member Registration Campaign

A cooperative must register sufficient members to fulfill legal requirements, obtain a critical social mass, and obtain a sustainable level of capital contribution inflows.

With that said, keep in mind the difference between what is legally required and what is feasible. For example, in the Dominican Republic the law requires a minimum of 200 members to form a public service cooperative. It is highly unlikely, however, that 200 relatively poor rural families would be enough to form a financially sustainable electric cooperative.

To illustrate the importance of achieving a critical social mass, consider creating an electric cooperative in a region where 10,000 families live without electricity. Ideally, all 10,000 families would become registered members of the cooperative. However, rarely is it possible to get 100% of the population to sign up. When project proponents find some who do not want to become members, it should not be cause for alarm. Yet if a majority does not sign up, project feasibility must be seriously reconsidered. If granted a concession, by law the cooperative will have to provide service to both members and non-members and project proponents must ask themselves what would happen when faced with significant challenges if the cooperative lacks majority consumer support. What would happen, for example, during a hostile takeover attempt or unfavorable legislation that threatens to eliminate electric cooperatives?

A cooperative must register sufficient members to fulfill legal requirements, obtain a critical social mass, and obtain a sustainable level of capital contribution inflows.

A critical social mass is also necessary to provide sufficient capital inflows. Continuing with the above illustration of a region with 10,000 families, if the project costs an estimated US$10 million and all 10,000 families join the cooperative, a US$1,000 contribution per family could finance the whole project. However, if only 1,000 families register, with a commitment to pay US$1,000 each, the cooperative would have only one-tenth of the financing required. In this case, the cooperative would have to collect more money from each member, look for other sources of financing, register more members, or decide not to go ahead with the project.

An innovative member registration campaign helps attract new members. The campaign can use a variety of methods, such as a series of simple face-to-face conversations, house-to-house visits, small group meetings in homes, or large community gatherings.

The creative abilities of organizers and promoters are an essential ingredient in selecting an approach (or a combination of approaches) to recruit new members. The final goal must be to recruit as many members as possible. Promotional material for distribution may include pamphlets, brochures, comic strips, and other types of printed material, as well as TV, radio, and loudspeakers. The idea is to convince people to become part of the project. This requires educating them about what a cooperative is, as well as informing them about the benefits and responsibilities of membership.

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Sufficient membership application forms should be available at all times for interested parties who would like to sign up on the spot. Promoters should also be ready to receive registration payments from individuals during meetings or at gatherings. One of the most sensitive points in this process is how money will be handled. For the success of the project, it is vital that project money be managed with total transparency. Ideally, each member would go directly to the bank to deposit their registration fee, but this is not always a practical solution due to time, distance, and bank location. In such cases, it is important to establish mechanisms for trustworthy individuals to receive registration fees and other funds, and issue receipts. The Steering Committee should maintain and update project records, archives, and other pertinent databases so that exact and reliable information is readily available.

STEP 13: Founding Assembly Meeting

The Founding Assembly meeting requires significant preparation by the Steering Committee. The Committee must arrange all logistics for the event, based on the number of people expected.

National laws often have requirements for notifications and invitations to the Founding Assembly. The Steering Committee must comply with these requirements to assure that all prospective members receive advance notice of the meeting and that they have all the necessary information to participate.

The Assembly is conducted according to a pre-established agenda. Deliberations are governed by the debate rules prepared by the Steering Committee for the meeting.

The most important actions taken at a Founding Assembly Meeting are approving the bylaws, and electing the Board of Directors.

STEP 14: Board Meetings

Those elected to the Board of Directors should meet immediately after the adjournment of the Founding Meeting or as soon thereafter as conveniently possible. In most cases, those elected to Board of Directors should then conduct internal elections for positions indicated in the bylaws, e.g. the president, vice-president, secretary, and treasurer. Results of elections are recorded in the official minutes of the cooperative.

Following the internal elections, the president of the Board of Directors should be authorized to immediately register the cooperative with the appropriate government agency to obtain full legal recognition.

Thereafter, the Board of Directors should conduct regular and special meetings as established in the bylaws, starting as soon after the Founding Assembly as possible. The Board should use the first regular meetings, and whatever special meetings as may be necessary for the President to call, to formulate an administrative and organizational plan for the cooperative. One of the first tasks is to develop an implementation plan.

Implementation Plan

The Board of Directors should develop a written plan to organize the management and operational aspects of the cooperative to achieve the cooperative's goals. The implementation plan not only serves as an internal guide for the organization but also as a tool to inform the membership about expected progress. It identifies the organizational structure, administrative functions, requirements for staffing, equipment, and other needed resources, as well as a schedule to accomplish action items.

Preparing an implementation plan may require technical assistance from external advisors or consultants. Implementation plan action items include:

- Obtain legal status for the cooperative.
- Acquire office and operations center locations.
- Hire a manager and assign him or her functions and responsibilities. (Expert advice should be sought for this key task.)
- Comply with financial accounting standards.
- Transfer saved funds to checking accounts.
- Register authorized signatures to draw funds.
- Obtain outside advice and assist the General Manager during power purchase negotiations.
- Obtain advisors to assist the General Manager, e.g. in proceedings related to concession licensing and tariffs, setting up electric service requirements, defining project costs; etc.
- Acquire electrical systems within the area.
- Assist the General Manager in specific proceedings, e.g. financial, acquiring government endorsements, etc.

The implementation plan is the cooperative's road map to a successful launch. The Board of Directors must make it a priority and take all steps necessary to fulfill this responsibility.

STEP 15: Legal Steps

Important legal steps vary from country to country and may include the following.

Obtain Legal Status

The process and time required to obtain legal status for a business varies widely from country to country. The work of Hernando De Soto illustrates this point. In his book *El Otro Sendero* (The Other Path), De Soto describes documenting the time required to legally incorporate a microenterprise for sewing garments in Peru. The time required: 289 days. De Soto sent researchers to Tampa, Florida to carry out the same exercise. The time required: 3.5 hours.[13] In most developing countries, electric cooperative organizers should be prepared to spend more than 3.5 hours to obtain legal status.

Obtain the Service Territory Concession

Project proponents must approach the appropriate government agencies or regulators to obtain a concession or permission authorizing the cooperative to operate as an electric utility.

Construction Authorization or Contracts to Transfer Existing Electrical Infrastructure Ownership

If the cooperative is being formed in a region that does not have existing electric service, authorization must be obtained in order to build an electric system. In areas where the electric infrastructure already exists, the transfer of assets and infrastructure to the cooperative must be delineated in a formal binding document.

If the cooperative is being formed in a region that does not have existing electric service, authorization must be obtained in order to build an electric system.

Obtain Tariff Authorization

Proposed tariffs should be approved by the regulatory agency prior to commencing operations.

STEP 16: Capitalization Plan

Capitalization refers to the amount and source of the money required to create and operate the

[13]El Otro Sendero, Hernando De Soto, ISBN 968-13-1769-6, Copyright 1987, por Editorial Diana, S.A. de C.V.

business. A cooperative capitalization plan usually includes funding from both members and outside sources such as donors or lending institutions. Electric cooperatives are generally capitalized with the following major sources:

- Registration fees
- Revenue in excess of expenses (margins)
- Contributions in aid of construction
- Loans and grants

Member Contributions

Members provide revenue in two ways. First, they pay a small registration fee when the individual joins the cooperative (usually around US $5). Second, they pay for the electricity they consume.

Capital received from members is called equity. Member's equity consists of their registration fee and their share of the margins (revenue in excess of expenses) remaining each year after all cooperative expenses have been paid. Margins are allocated to each member's equity account annually, usually in direct proportion to their purchases of electricity.

Members may also provide contributions to the cooperative in the form of "construction aid" for line extensions, new services, upgrades, etc. These funds are generally credited against the cost of the project (to reduce debt) and are not included in the member's equity.

Equity, representing ownership by members, is retained by the cooperative for specific periods of time to provide financial reserves and meet lender requirements. If the cooperative is financially successful, the Board of Directors may elect to return portions of equity to the members at some future date. In the United States, common practice is to return equity to members 10 – 20 years after it was allocated (assuming the cooperative will remain financially solvent thereafter).

Loans

Loans are the other major source of capital for a cooperative. Building an electric distribution infrastructure is a capital-intensive effort, and it is impossible to generate sufficient member funds to cover the costs of constructing a distribution system. Cooperatives typically seek loans for construction of long-lived assets and amortize the cost of building the electric system over the life of those assets. This is an appropriate method to finance system construction, expansion, and upgrades. Power lines and substations built well today will remain in service for more than 30 years. By spreading the loan repayment schedule over 30 years, both current and future consumers who are benefiting from the system are helping to pay for it.

Loans for major construction projects may be available from government financing entities or international institutions. The Board of Directors should explore all available long-term loan sources, including savings and loan associations, commercial banks, and insurance agencies.

Preparing a loan application to fund a new cooperative is a significant task. The Board should assemble a technical team for the purpose, including financial experts (e.g. the advisor(s) who developed the financial plan), an attorney, a licensed public accountant, and others as needed. The application package should clearly describe how the loan funds would be used. Financial information demonstrating how the loan will be repaid is an integral part of the loan application. Much of the required financial information for the loan application will be in the cooperative's business plan.

Once established, cooperatives often fund short-term borrowing needs (up to 1 year) through local banks. A line of credit is often used to acquire a portion of the money needed for operating capital and interim funding for construction projects prior to receiving a long-term loan. Typically, the total amount of borrowing is limited, and these loans must be renewed annually. They do not take the place of a long-term loan.

Grants

Grants may be available from donor agencies, government entities, and other organizations. Certain grants may be designated to support the start-up phase of a cooperative prior to generating funds from members or lenders.

STEP 17: Prepare to Commence Operations

A variety of tasks must be accomplished prior to beginning operations at a new cooperative, starting with hiring a General Manager.

Hiring a General Manager

An effective General Manager is essential to the success of a cooperative. Minimum requirements for this position should be established prior to hiring the manager. Be sure to create a policy defining the relationship between the General Manager and the Board of Directors. The Board normally contracts the General Manager, and in turn, the General Manager hires the rest of the personnel and directs the day-to-day operations of the cooperative.

A General Manager should possess three key attributes: academic preparation, electric sector experience, and the ability to work with other people. While the position description may include numerous other requirements, these three are the most critical.

Other factors to be considered in assessing manager candidates include:

- References
- Base wages
- Health certificate
- Background check or police certificate
- Valid driver's license
- Experience in financial management, engineering, procurement, etc.
- Languages

Note that while some of the above criteria may not be acceptable job screening criteria in the U.S., they are not only accepted but even expected in some developing countries.

The Board of Directors determines which criteria are required and which preferred. A position description outlining these items should be prepared. The position should be publicized as broadly as possible, including a timetable for applications. After the close of the application period, the Board evaluates resumes, conducts interviews and background checks, and makes a selection.

Preparing a Strategic Plan

A strategic plan must also be prepared to provide direction to management and establish a guide for the cooperative. The plan includes the cooperative's social and economic purposes as well as a broad outline of operations.

A strategic plan typically includes the following elements:

- Mission
- Vision
- Values and principles
- Strategic targets
- Key factors for success

The Board normally contracts the General Manager, and in turn, the General Manager hires the rest of the personnel and directs the day-to-day operations of the cooperative.

- Key business strategies
- Plans and programs
- Goals
- Execution timelines

Policies

The cooperative must sign contracts with all its members and clients prior to commencing sales of electricity.

Policies must be developed to provide more detailed information regarding cooperative operations.

Organizational Chart and Job Descriptions

An organizational chart and job descriptions must be prepared. The General Manager typically participates in the development of these documents.

Contracts with Users

The cooperative must sign contracts with all its members and clients prior to commencing sales of electricity. Initiate this process as soon as the service area concession is obtained.

Operational Infrastructure: Office, Warehouse, Etc.

Before operations can start, the cooperative has to construct or rent office space, warehouses, workshops, and any other infrastructure required. These facilities must be adequately equipped with computer systems, furniture, telephones, etc.

Install Computer System: Consumer and Business Information

A computerized system is the best way to maintain consumer and business records. At a minimum, it must be capable of preparing invoices and automating reports. Useful software programs include those for consumer database management, billing, financial and plant accounting, engineering, operations, and human resources recordkeeping. Purchasing a suite of software programs from a single company is often the best approach, rather than selecting programs from different vendors or creating custom software. However, carefully consider each option before making a final decision.

A contract for on-going support and maintenance is critical, particularly in rural areas where other support resources are nonexistent. Nevertheless, before selecting a software package, carefully review the cost of the ongoing support and maintenance packages and compare that to the cooperative's needs and ability to pay. Begin by surveying the local and international markets for software packages and prices, and enlist the advice of experts before deciding on a final software package or creating a custom software package. Computer hardware and software solutions are available for all sizes of businesses from a variety of companies, including some that specialize in electric cooperatives.

Engineering and Technical Services

The necessary infrastructure for the distribution of electricity must be in place prior to the cooperative becoming operational. If an existing electric system is to be acquired, all necessary improvements must be completed prior to the start of operations. The cooperative has to either contract or hire an engineering staff as well as linemen and equipment maintenance professionals. The size of this staff depends on the cooperative system's size and complexities.

Care should be given when the cooperative is to acquire the engineering and technical staff of an existing utility. Often public utilities overstaff these departments.

In addition, the cooperative needs to acquire the necessary field equipment, computers and software for the tasks at hand. Typically, software used to model load flows and a geographic information system (GIS) software package are recommended. Hand tools and mechanized tools must also be procured. The cooperative should seek experts in distribution system operation and maintenance to develop a complete list of necessary tools, equipment, and software.

Training

Training is important at all levels of the cooperative, including for the Board of Directors, management, and staff. Training manuals or modules must be acquired or developed and tailored to the unique culture of the country. Sometimes training information must be translated into the local language. Whenever possible, professional trainers should be contracted to provide a "training-of-trainers" instruction course on specific cooperative topics.

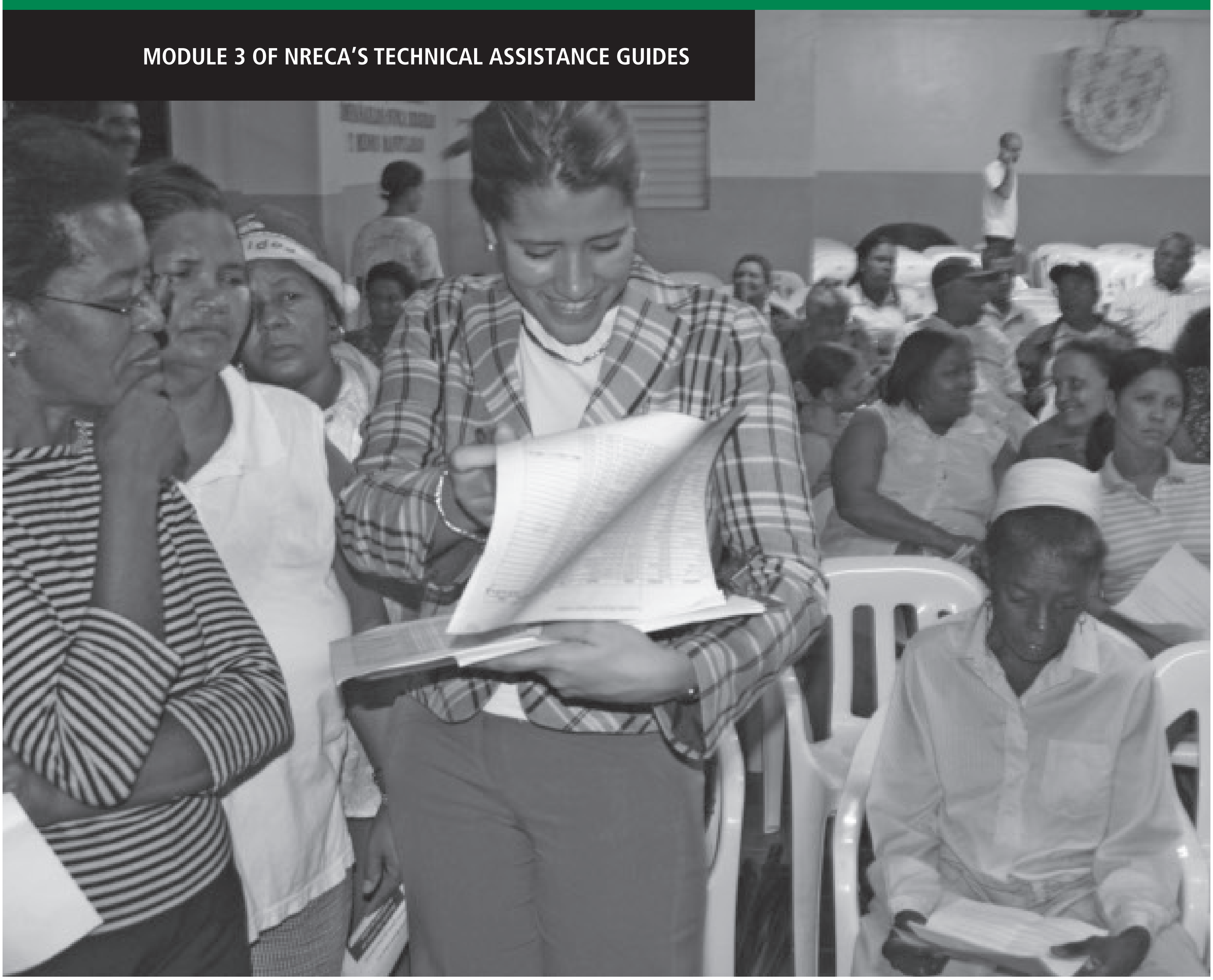
STEP 18: Commence Operations

The commencement of operations is the culminating step. After all else has been successfully completed, the day finally arrives when the electric cooperative begins to operate.[14]

[14]For further recommendations on electric cooperative formation, see *How to Organize a Cooperative*, op.cit.

Roles and Responsibilities of Electric Cooperative Boards of Directors

MODULE 3 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



3

EXECUTIVE SUMMARY

The success of any institution depends on the quality, knowledge, experience, and integrity of its Directors and employees. This is also true for electric cooperatives. Being a cooperative does not guarantee success. Directors of electric cooperatives must know their role, their responsibilities and the responsibilities of the General Manager.

For the orderly operation of an electric cooperative, the Board of Directors must understand and ultimately fulfill their responsibilities. Directors also need to understand the boundaries of their responsibilities, so as to refrain from interjecting themselves where it is neither necessary nor convenient that they do so. NRECA prepared this module as a guide to help the directors of electric cooperatives to better understand their responsibilities and boundaries.

Cooperatives have existed for more than 150 years and electric cooperatives for more than 70. In that time, much experience has accumulated regarding how the boards of cooperatives should function.

The Board of Directors is the representative body of the members of the cooperative. It represents the legitimate cooperative owners and acts on their behalf. The owners elect the Board and place in its hands the administration of the assets and responsibilities of the cooperative. The Board of Directors has five principal functions:

1. *Legal:* Ensure the legal right of the cooperative to exist

2. *Trusteeship:* Act in the best interest of the members

3. *Planning:* Develop programs and carry out plans based on ideals that reflect the thinking of its members, with realistic goals adjusted to the purposes of the cooperative

4. *Resources:* Assure the availability of basic resources, including personnel, loan funds, wholesale power, and revenue, according to the cooperative's size and needs

5. *Control:* Monitor operations to assure compliance with Board policy, budgets, member relations, loan covenants, contractual compliance, and long-range planning

In these five areas, Directors must delicately balance their responsibility to establish policies and procedures for the cooperative with their responsibility to allow the staff to control day-to-day operations.

In addition to the above responsibilities, Directors also have certain duties and rights. Director duties include loyalty, obedience, and due care. Loyalty requires a Director to be loyal first to the cooperative entity. Obedience requires a Director to perform his or her duties in accordance with applicable laws, bylaws, contracts, and policies. Due care requires a Director to perform his or her duties as a member of the Board, or any committee of the Board upon which he or she serves, in good faith, in a manner he or she reasonably believes to be in the best interests of the cooperative, and with the care that an ordinarily prudent person in a similar position would use under similar circumstances.

Director rights include access to management personnel, access to books and records, proper and timely notice of meetings, ability to review

The Board of Directors is the representative body of the members of the cooperative. It represents the legitimate cooperative owners and acts on their behalf. The owners elect the Board and place in its hands the administration of the assets and responsibilities of the cooperative.

meeting minutes, access to outside advice, and ability to hear the prudent judgment of others.

Serving on a Board of Directors carries several responsibilities. Each Board member must conduct himself or herself in a professional manner that properly reflects the cooperative's mission. This is typically called a code of ethics. Key code of ethics considerations are:

A Board is extremely important to the success of the organization. Boards represent owners and have final responsibility for the organization. It therefore follows that Board members must understand their duties and responsibilities and diligently carry them out.

- representing the interests of all – not special interests
- respecting and supporting the majority decision of the Board
- being prepared to make constructive decisions
- acting as a trustee of the cooperative

Directors will find success if they thoughtfully manage the interrelationships between the Board and General Manager. This module identifies several distinct duties that delineate the responsibilities of the Board and management. It also emphasizes the need to recognize the personalities of each Board member and management staff.

Proper meeting conduct, when Directors review operational results, plan, and make decisions is also important to the success of the Board.

Finally, not everything goes right. Board members may make mistakes and create difficulties. Some problem areas include:

- attempting to be a spokesperson for the cooperative
- expressing personal and public opinions on Board actions
- bypassing the chain of command
- acting out of friendship with staff members
- procrastinating
- failing to establish goals and objectives

Other handicaps to Board success include the oversimplification of issues, myopic focus on limited alternatives, unwillingness to try something new or discard old methods, making decisions from preconceived attitudes, paying attention only when certain topics arise, focusing decisions on a limited geographical area, and demanding perfection before going ahead.

This module will help guide prospective or current Board members of electric cooperatives, as well as those interested in establishing electric cooperatives.

INTRODUCTION

Every formal organization consisting of more than two people must establish an owners' governance group. In very small organizations that are not formally organized, not incorporated, and not government entities, the governance group consists simply of those individuals who have financial ownership in the organization. As an organization grows, in owners and/or employees, it formalizes this governance group.

Governance groups represent their owners. Generally, there are two types of governance groups: those created within private (non-government) organizations and those created for government entities at the national, regional or local level. This module focuses on the first group – private organizations.

In private organizations, the governance group is usually called a Board of Directors (or simply "the Board"). The Board represents the owners of the organization. However, it is important to note the four distinct groups within most organizations:

- *Owners:* These individuals have invested resources through money, property, or time to create and maintain the organization. A golden rule is that the organization must satisfy its owners. Without owners, there is no organization. Other than compliance with applicable laws, the owners have final say in all matters dealing with the organization.

- *Employees:* Owners hire management and staff to operate their organization. The employees work for the owners. Employees follow policies established by the owners.

- *Purchasers of the organization's services:* Every organization serves customers or consumers. These customers/consumers provide regular income to keep the organization going and create a return on the investment of its owners.

- *Resource providers:* Organizations provide goods or services. The organization must acquire raw materials, financing, training, and other support materials/information in order to provide services and earn a return for its owners.

As noted, employees work for the owners, customers purchase goods and services provided by the owners, and resource providers supply resources as needed by the owners. Again, the golden rule is that the organization must satisfy its owners.

In a cooperative, the owners are normally members as well as purchasers. However, in some cooperatives not all purchasers are also members.

Private organizations fall into two basic groups: profit and non-profit (also called not-for-profit) organizations. This module relates to non-profit organizations. Boards of non-profit organizations are generally less professional compared to Boards of profit organizations. This occurs for two primary reasons. First, non-profit organizations have difficulty attracting qualified candidates due to a lack of profit motivation and minimal (or non-existent) personal remuneration for Board service. Second, non-profit Board members usually work full-time elsewhere and cannot spend significant time on the non-profit Board.

Owners of formal organizations elect a Board of Directors, or other governance group. Regardless of its title, the Board must represent the owners. All democratic nations have ratified laws identifying responsibilities and limitations of Boards serving formal organizations. These laws state that elected Boards have the legal authority and responsibility to conduct the business of the organization on behalf of the owners. Concurrently, these laws also limit the involvement of individual owners (outside of the elected Board) to become involved in the affairs of the organization. For cooperatives, this means that cooperative members who are not part of the Board do not have the right to become involved either in cooperative operations or in setting policy.

All democratic nations have ratified laws identifying responsibilities and limitations of Boards serving formal organizations.

A Board is extremely important to the success of the organization. Boards represent owners and have final responsibility for the organization. It therefore follows that Board members must understand their duties and responsibilities and diligently carry them out.

This module identifies duties, responsibilities, limitations, and problem areas of rural electric cooperative Boards that are non-profit and legally incorporated under the laws of applicable governing bodies.

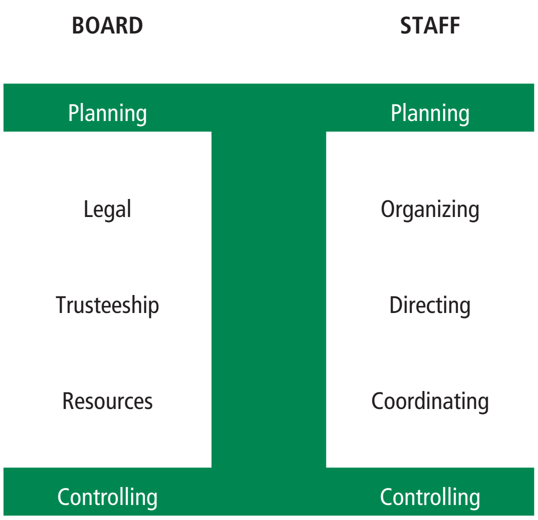
I-BEAM FORM OF MANAGEMENT

The I-Beam form of management is a method of assigning responsibilities between the Board of Directors and staff, or employees.

Figure 1 shows the I-Beam form of Management. In construction, the "I-Beam" is a strong structural element. In management, the I-Beam embodies the same strength and clearly illustrates how a Board of Directors and its staff should collaborate and function.

Both the General Manager and Board perform planning and controlling functions to ensure that plans are completed effectively.

Figure 1. I-Beam Form of Management



In the I-Beam model, certain functions are shared between the Board and staff, who are represented by the General Manager. These include planning and controlling. Both the General Manager and Board perform planning and controlling functions to ensure that plans are completed effectively.

While there are common functions, the Board and General Manager must also perform distinct functions and responsibilities. The Board is responsible for the legal aspects of the cooperative, a trustee relationship with the owners, and providing resources. The General Manager must not attempt to perform these functions for the Board. Similarly, the General Manager's responsibilities include organizing, directing, and coordinating all cooperative work functions that the Board must not perform.

If the Board and General Manager jointly plan the objectives of the cooperative effectively, then each should be able to carry out their respective functions without causing frustration to the other.

BOARD RESPONSIBILITIES

Board responsibilities are critical to any organization. In Figure 1, the "I-Beam" diagram listed five distinct duties and responsibilities of the Board. A detailed explanation of each Board function contained within the "I-Beam" structure follows.

Board Responsibilities – Planning

Planning is a significant task of any cooperative's Board. Whereas the staff carries out Board plans and operates the organization, the Board must plan continually, with an eye to the cooperative's future. In establishing plans, the Board must understand the goals and objectives of the cooperative members.

The Board plans for both the long term and short term. Therefore, the Board must consider and adopt all plans with respect to all of the following:

- Seek ideas, viewpoints, objectives, major goals, and results desired by the cooperative members.
- Determine, in consultation with the General Manager, the guiding policies of the cooperative; review policies at least annually to ascertain that they meet changing operating conditions and comply with all policies, procedures, and regulations of lending, regulatory, and administrative agencies.
- Review and approve broad operating programs, services, and activities developed and recommended by the General Manager, taking into account the costs, the benefits and the financial conditions of the cooperative.
- Review and approve the annual work plans and budgets to achieve the desired end results from operations and to provide the best possible service to the members.
- Consider and adopt, in consultation with the General Manager, broad personnel and wage and salary policies essential to provide opportunities for growth and

development of employees, including annual revisions to wage and salary plans and wage adjustments.

- Consider and adopt, in consultation with the General Manager, financial plans and policies essential to maintain a sound financial structure for the cooperative.

- Determine, in consultation with the General Manager, policies for maintaining good member, public, and governmental relations and programs for community and economic development.

- Consider and approve long and short-range plans to ensure an adequate and reliable supply of power at the most reasonable cost for cooperative members.

- Schedule and conduct effective Board and member meetings in accordance with the cooperative bylaws.

Board Responsibilities – Legal

Legal responsibilities can present challenges for individuals serving on cooperative Boards. In many cases, Board members may not be familiar with legal matters pertaining to electric cooperatives. Therefore, the Board should hire an attorney who reports directly to the Board. Ideally, the attorney should have knowledge of electric cooperative law. At a minimum, he or she should be thoroughly familiar with business law, as well as have a desire to learn its application to electric cooperatives.

The Board has a responsibility to establish and maintain the legal status of the cooperative as follows:

- Comply with legal requirements as set forth in the cooperative's articles of incorporation, bylaws and other applicable regulations. Select and appoint qualified legal counsel to the Board.

- Study, consider and propose revisions and other changes to the bylaws, as necessary or required.

- Review and approve all major legal contracts, including wholesale power contracts, construction contracts, and loan agreements.

- Assure proper issuance of membership certificates and accounting for memberships.

- Ensure that complete and accurate minutes of Board and member meetings are prepared, maintained, distributed, and that the signed originals are kept safe.

Board Responsibilities – Trusteeship

According to *Webster's Dictionary*, a "trustee" is "a person appointed to administer the affairs of a company" or "a person who holds title to property for the benefit of another."[1] "Trusteeship" is the act of performing trustee functions. Thus, Board members are entrusted with the owner's (the membership's) interests in administering the Cooperative's affairs. Boards of Directors have a legal responsibility to carry out this function.

Board members must act as trustees of the membership as follows:

- Conduct well-planned membership/representative meetings to adequately inform the members/representatives, obtain their ideas and suggestions, develop leadership among the members, and promote understanding and acceptance of the cooperative's objectives, goals, policies, plans, and programs.

- Conduct well-planned and timely membership meetings as provided in the cooperative's bylaws.

[1] *Random House Webster's Dictionary*, 4th edition, (New York: Ballantine Books, 2001).

Board members are entrusted with the owner's (the membership's) interests in administering the Cooperative's affairs. Boards of Directors have a legal responsibility to carry out this function.

- Stay informed about changing member needs and how the cooperative might meet these needs on a viable financial basis.

- Inform members about cooperative operations through newsletters and other publications, annual reports, and membership/representative meetings.

- Be familiar with and comply with Board policies and the bylaws of the cooperative.

- Stay informed. Develop skills and understanding to enhance performance as a Board member and arrange for regular training programs to keep Board knowledge and abilities growing.

- Assist new Board members to develop a greater understanding of their responsibilities and authority.

- Participate in outside activities as deemed advantageous to enhance the understanding of the cooperative by members, the community, and national leaders, as well as to strengthen cooperative operations.

- Ensure that continuous programs for member, public, and governmental relations are carried out to develop understanding and support for the cooperative.

- Keep members informed of problems faced by the cooperative that require their support, and of the need for changes that may affect them.

- Protect the assets of the cooperative and assure the provision of adequate insurance coverages.

- Protect the assets of the cooperative by fully complying with policies, regulations, and mortgages requirements.

- Select and appoint qualified independent financial auditors annually.

- Select banks for cooperative funds and authorize individuals to sign bank documents, including checks, on behalf of the cooperative.

- Plan and conduct effective Board meetings, with enough frequency to keep Directors well-informed, to provide needed policies, facilities and financing, and to assure desired results.

- Establish policies governing the payment of travel, out-of-pocket, and other expenses of Directors and employees.

- Approve the appointment of principal consultants to the cooperative, including contracts and agreements for services.

- Assure that basic policies are developed for competitive bidding of large material and supply purchases, and major purchases of equipment, vehicles, and land, etc.

It is up to the Board to establish policies and procedures to provide necessary resources. The Board should also monitor the availability of resources on a regular basis.

Board Responsibilities – Resources

An organization cannot exist without resources. In this context, "resources" means personnel, funding, wholesale power, and revenue. It is up to the Board to establish policies and procedures to provide necessary resources. The Board should also monitor the availability of resources on a regular basis.

The Board must assure the availability of four types of basic resources according to the size, needs, and purposes of the cooperative:

1. *Personnel:* Authorize employee positions and numbers of employees, hire a qualified General Manager, delegate authority with clearly spelled out responsibilities, and provide adequate and safe working conditions.

2. *Funding:* Establish policies to assure proper financial operations, secure loan sources, and clearly define when prospective consumers must contribute towards the cost of new

construction and how those contributions will be calculated.

3. *Wholesale power:* Secure long-term sources of wholesale power at reasonable rates, either through purchased power or generated power.

4. *Revenue:* Establish rates and fees to cover all costs and provide for margins consistent with good business practices.

Board Responsibilities – Controlling

The Board must establish proper controls to evaluate whether the organization is achieving its goals and objectives. The Board cannot simply assume that all policies are being adhered to and that goals will be achieved. It is essential to monitor and evaluate cooperative operations to assure compliance with Board policy, budgets, loan covenants, contractual requirements, and long-range planning.

The Board establishes controls and monitors effectiveness of Cooperative operations through the following seven methods:

1. *Board policy:* Establish the cooperative's policies and monitor compliance with those policies.

2. *Budgets:* Establish long-range financial plans and annual budgets and monitor compliance.

3. *Member relations:* Promote a workplace environment where Cooperative members are the organizational focus, and monitor member satisfaction.

4. *Loan covenants:* Understand the general concepts of major loan agreements. Assure that funds are correctly used and that loans are paid on time.

5. *Contractual compliance:* Monitor performance of major contracts frequently.

6. *Long-range planning:* Establish long-range construction and financing plans, update when needed, and compare actual performance with the plan projections.

7. *Outside assistance:* Engage auditors, legal counsel, and other professionals to assist in the Board's control functions.

INDIVIDUAL BOARD MEMBER'S DUTIES AND RIGHTS

Directors have both duties and rights. Duties are responsibilities that Directors have while serving on the Board; rights are those items each Director is entitled to in order to properly carry out his or her duties.

Director Duties

A cooperative Director has several duties. Primary duties include:

- Loyalty
- Obedience
- Due care

A Director must be loyal to the cooperative. This means not engaging in personal activities that can be construed as conflicts of interest, maintaining information confidentiality, and not bringing harm to the cooperative as a result of personal action. For example, a Director publicly expressing strong personal opinions in opposition to an official Board action contradicts loyalty to the cooperative.

Occasionally, a Director cannot avoid a particular conflict of interest. For instance, a Director may have a financial interest in a contract under consideration by the Board. In this situation, the Director should disclose the conflict of interest to the Board of Directors at a legally constituted meeting, and that Director should refrain from voting on the issue.

The Board must establish proper controls to evaluate whether the organization is achieving its goals and objectives.

Such actions are contrary to the Director's own feelings or inclinations. An action by a Board at a legally convened Board meeting is an action by the entire Cooperative. All Directors should support such action. The duty of loyalty fails to apply only if a Board action is clearly illegal, as stated by proper legal counsel. In the rare occasion of an illegal Board action, the concerned Director should state his legal concerns on the record at the Board meeting, vote against the issue, and seek legal counsel following the meeting.

The duty of obedience requires a Director to perform his or her duties in accordance with applicable laws, including national and regional laws and ordinances, cooperative bylaws, contracts, loan agreements, policies, and safety requirements.

The duty of care requires a Director to perform his or her duties in good faith, in a manner he or she reasonably believes to be in the best interests of the cooperative, and with such care as a prudent person in a similar position would use under similar circumstances. The duty of care also involves due diligence. In considering issues, a Director should attempt to get all relevant information and should be cautious and prudent in decision making.

Other duties of Board members include:

- Attend Board meetings regularly.
- Become knowledgeable.
- Come to meetings prepared.
- Contribute to meetings by expressing views.
- Consider the points of view of others.
- Make decisions – do not procrastinate.
- Represent the cooperative professionally.
- Assume Board leadership when asked.
- Keep the General Manager informed.
- Respect the relationship between the Board and the General Manager.

Director Rights

Directors also have rights. These include unrestricted and free access to management through the General Manager, and to cooperative files and records. Directors have the right to access financial and accounting records, long and short-range plans, Board minutes, policies, procedures, and legal opinions. A Director has the right to ask questions of appropriate management staff and to review operational and financial records.

However, three areas of caution must be observed with respect to such access. First, the Director's access should be for official, not personal, purposes. Second, the proper chain of command should be followed. This means the Director should address questions or requests to the General Manager. The General Manager, in turn, then can either authorize the Director to contact other staff, or the General Manager can have other staff provide the information desired via the General Manager's office. Third, some information (e.g. employee personnel and salary records) is considered sensitive and may not be available to individual Directors. Directors must observe the confidentiality of all information.

If a Director feels he or she has been denied access to information without proper cause, that Director should address his or her concerns to the Board President or bring it up at a Board meeting.

Directors' rights include the right to receive timely notice of all upcoming meetings, access to minutes of Board and committee meetings, access to external advice (legal, auditors, engineering, etc.), and access to the prudent judgment of others, such as the right to hear opinions of staff and of other cooperative members. If external advice is fee based, Board approval may be required in order to incur the expense. In addition, opinions of staff should be obtained through the proper chain of command or during a legally constituted Board or committee meeting.

BOARD MEMBER CODE OF ETHICS

Serving on a Board of Directors carries several responsibilities, as described in previous sections. Each Director must also conduct himself or herself in a professional manner, properly reflecting the cooperative. The code of ethics for cooperative Board members includes the following points:

- Represent the interests of all – no special interests.
- Do not use the cooperative for personal gain.
- Respect confidential information; keep it confidential.
- Respect and support the majority decision of the Board.
- Approach all Board issues with an open mind.
- Be prepared to make constructive decisions.
- Do nothing to violate the trust of those who elected you.
- Focus your efforts on the mission of the organization, not on personal goals.
- Support Board decisions.
- Do not overstep your authority and responsibility.
- Consider yourself truly as a "trustee."

RELATIONSHIP BETWEEN THE GENERAL MANAGER AND THE BOARD

This section compares major duties of the Board and with those of the General Manager. As stated previously, the Board has three functions distinct from those of the General Manager, while they share planning and controlling responsibilities with the Board. It is important to understand how the Board carries out its five basic responsibilities without overstepping its role, in such a way as to strengthen the ability of the General Manager and staff to carry out their responsibilities.

"Leadership is a delicate balancing act among personalities. The relationship between a Board and General Manager is represented by lines on an organization chart. If that were the way it played out, everything would be in balance. When you include the people, suddenly it is less a science than an art. Each and every Board member has a personality, and a successful Board member and General Manager must understand how they mix and the contribution they make."

– Anonymous

In carrying out their respective responsibilities, it is critical that the General Manager and Board members understand and respect the fact that each has a personality.

Table 1 illustrates the duties of the Board and the General Manager (and staff) in concrete terms.

The following is a general statement that is often included in cooperative policies and that appropriately conveys the differing duties of each party.

A. The Board of Directors shall:

1. Establish Board directives including policies, plans and programs; exercise sound financial control in attaining cooperative goals and objectives.

Each Board member must conduct himself or herself in a professional manner, properly reflecting the cooperative.

Table 1. Responsibilities of the Board and General Manager

BOARD	GENERAL MANAGER
Establish policy	Carry out policy Develop procedures Report policy violations to Board Recommend policy changes
Long-range planning	Help Board identify needs Transform policy into work plans, budgets and implementation plans Keep Board informed
Monitor finances	Responsible for revenue and expenses Prepare monthly reports Advise Board of problems and opportunities
Approve annual budgets	Develop budgets Compare budget and actual expenses Operate within approved budget Obtain Board approval for items "out of budget"
Monitor operations	Have day-to-day responsibility for operations Advise Board Chairman immediately of major concerns Obtain Board approval for significant unanticipated situations Report monthly to Board
Approve major contracts	Negotiate as appropriate Make recommendations to Board Manage approved contracts
Listen and respond	Resolve problems Respond to opportunities Manage member/owner, lender, and public relations

2. Conduct cooperative business in unison as a Board and not as individual members. Individual Board members shall not commit the Board without being specifically granted such authority by the Board.

3. Individual Directors shall refrain from directing and discussing management and day-to-day problems with cooperative employees, and recognize that the flow of management and day-to-day operations shall be through the General Manager.

B. The General Manager shall:

1. Perform functions and duties as directed in the General Manager position description.

2. Carry out the policies, plans and programs instructed by the Board.

3. Report to the Board at Board meetings regarding cooperative activities, progress on Board directives, problems in meeting Board directives, and recommendations on Board directives as applicable.

Between Board meetings, meet with the Chairman of the Board to advise and to receive consultation as needed.

PROPER MEETING CONDUCT OF DIRECTORS

Board members will spend a significant amount of time in Board and committee meetings. The following points are important for Directors to remember:

- Prepare for the meeting.

- Attend meetings – do not find excuses for absence.
- Take part in discussions.
- Keep discussions focused on the issues.
- Understand the basics of parliamentary procedures.
- Be flexible and polite.
- Golden rule: compromise.
- Learn to listen.
- Work toward consensus on issues.
- Focus on the organization's mission.

COMMON MISTAKES AND HANDICAPS

Several common mistakes and errors in judgment can handicap Board effectiveness. The following is a brief synopsis of situations to be avoided.

Common Mistakes

Attempting to be a Spokesperson

Occasionally, individual Directors may feel overly confident and act as a spokesperson for the Board without Board approval. This might include giving interviews to the local newspaper or radio station about a Board action or speaking at a public event. The official spokesperson for the Board is its Chairman. Individual Board members are not Board spokespersons. Board members other than the Chairman should refrain from making public statements concerning the cooperative. Exceptions to this are private discussions and a Board member making public statements solely within his or her voting district.

Expressing Personal Opinions on Board Action

Refrain from expressing personal opinions on Board actions. Once the Board makes a decision, each Board member should support that decision. Dissenting opinions should be kept private. If Board action is felt to have been illegal, the concerned Board member should vote his or her opposition at the Board meeting and request the "no" vote be noted in the Board minutes, and discuss the concern with the cooperative's attorney.

Bypassing the Chain of Command

A successful organization requires a proper chain of command. In a cooperative, Board members should direct all questions to either the Board Chairman or General Manager. Board members should not direct questions to staff members. The General Manager may authorize individual Board members to contact staff members directly on particular issues, but direct staff contact should be limited.

Friendship with General Manager and/or Staff Members

When possible, Board members should refrain from becoming friends with the General Manager and/or staff. Professional discourse is perfectly acceptable, but friendship often clouds professional relationships. Sometimes friendships cannot be avoided. In those instances, the Board member should try to refrain from discussing cooperative issues and base the friendship on a non-business foundation.

Failure to Establish Comprehensive Goals and Objectives

The Board may fail to establish complete and definitive objectives and goals for cooperative operations. This can happen if the General Manager has not provided the Board with timely and necessary information. However, it can also happen through Board procrastination. For example, a Board may approve an annual budget without asking questions about how estimated revenue was calculated, or what the relationship is between kilowatt-hour sales and purchases, or how operating expenses were determined, and so on.

Procrastination

A Board member's duty is to focus on the big picture and let the General Manager and staff manage the details.

Board meetings are often two to four hours in length, once a month. During that time, reports must be reviewed, policies set, major purchases approved, and actions taken to correct problems and/or take advantages of opportunities. This activity must then be repeated at the next meeting. There is no time to procrastinate! Boards should take action on a timely basis. Sometimes all the information desired is not available when it is time to make decisions. In such instances, Directors must be ready to make decisions with the best available information. When timely decisions are not made, problems compound and subsequent meetings become overloaded. When meetings become overloaded, the quality of Board decisions often suffers.

Micromanaging

Boards can be tempted to assist management with overly detailed directions, in lieu of establishing broad guiding policies that allow management to make most operating decisions independently. Remember, the Board sets the policies and monitors implementation, while management carries out the policies and reports to the Board.

Focus on Details

A Director's duty is to focus on the big picture and let the General Manager and staff manage the details. However, Boards sometimes focus on statistics and minute details instead of results, losing sight of the larger implications for the cooperative.

Employee Morale

To evaluate the cooperative's performance, Directors typically focus on written and verbal reports from the General Manager, consultants, and/or key staff. It is also important, however, to evaluate employee morale. Employee relations can have a huge impact on the success and efficiency of the cooperative. Directors should foster the idea that they sincerely care about employees and encourage activities that result in boosting morale.

Short-range vs. Long-range Focus

It is often easy to become preoccupied with present events and neglect the future. Directors may become consumed with short-range plans to the detriment of creating long-range goals. Focusing on today, this month, or this year obscures thinking and planning for three-, five-, and ten-year goals. Likewise, too much attention may be given to reviewing past events, and too little attention to determining long-range policies and plans, and providing needed resources on a timely basis. A Board that neglects planning for the cooperative's future is not fulfilling its basic function.

Handicaps to Board Effectiveness

The following attitudes or actions by individual Directors can handicap efficient Board operation:

- Directors may oversimplify, maintaining that nothing should be excessively complex. It is important to clarify and try to minimize problems as much as possible, but refusing to acknowledge a complex problem and failing to solve it often makes matters worse.

- Directors may fail to understand that multiple solutions may exist to a dilemma, and that each one can be modified or adapted, rather than wholly accepted or rejected. The Board must attempt to find the right alternative among many.

- Directors may be unwilling to attempt new approaches, or to discard old methods that cripple progress. The fact that something has never been done before is no reason for not doing it. On the contrary, refusing to try a new method or system simply because it is different from the old system entrenches current inefficiencies and costly operations.

- A Director who continues to talk after making a point merely wastes the Board's time and adds nothing to the discussion. This is equally true of the Director who says nothing until sensing that a decision has already been made. Agreeing with it if it proves successful and criticizing if it is not successful is just as harmful to the Board.

- Some Directors may have preconceived attitudes or prejudices toward ideas presented. They have stock answers for everything – often negative ones. Where there is a real problem, they refuse to exert the mental effort required to solve the problem, preferring a quick fix.

- A "restricted interests" Director pays no attention unless the matter under discussion is in his or her area of interest. This may be customer activities, or legal actions, or insurance. When those matters are before the Board, this Director is vocal and cooperative, but when other matters are before the Board, the Director stays silent.

- The geographically restricted Director sees all situations only in relation to the effect on a particular constituency and lacks a big picture view. This Director will support something only if it is 100 percent satisfactory to his or her group.

- Perfection seeking Directors are not willing to support efforts that present risks in any form or fashion. They rarely experiment. They must know that the results are certain and that procedures will be perfectly executed.

WHAT IT TAKES TO BE A GOOD BOARD MEMBER

This module has outlined the role, duties, and responsibilities of an electric cooperative's Board of Directors. The graphic depiction of the I-Beam form of management in Figure 1 identifies the major shared and independent responsibilities of the Board and General Manager. The discussion included the relationship between Directors and the General Manager, with special emphasis on delineation of duties. The module concluded with a summary of common mistakes made by Board members.

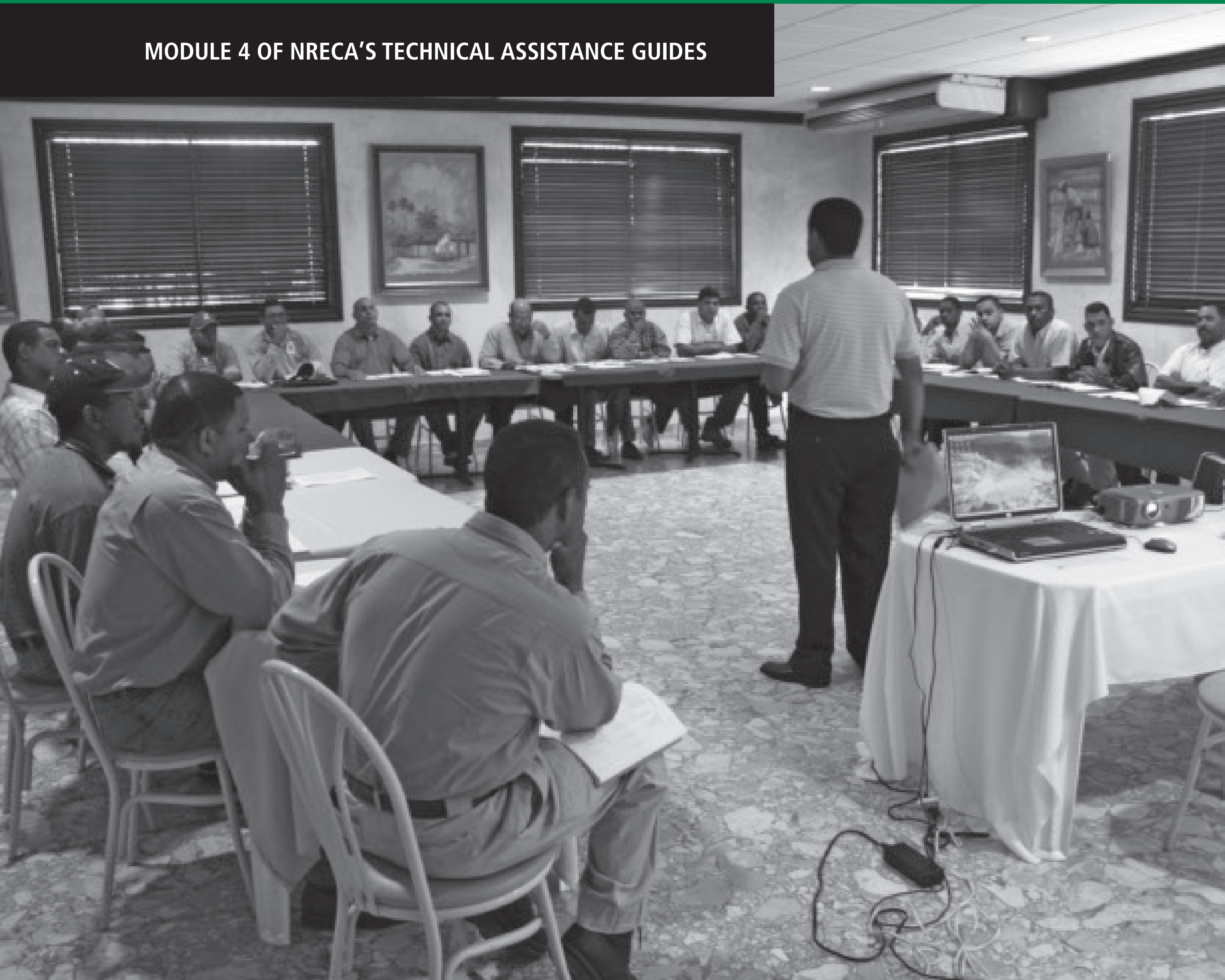
A Director who continues to talk after making a point merely wastes the Board's time and adds nothing to the discussion.

In summary, what does it take to be a good Board member?

- Desire to do what is right for the entire cooperative
- Willingness to learn
- Timely decision making
- Active participation in Board and committee meetings
- Honesty and impartiality
- Compromise and acceptance of Board decisions
- Communication on the level of listeners
- Consideration of personalities in reviewing results and making decisions

Business Plan for Rural Electric Cooperatives

MODULE 4 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



4

EXECUTIVE SUMMARY

This module of the Technical Assistance Guides presents an explanation of the role and importance of a business plan in the development and promotion of a new rural electric cooperative, as well as a section-by-section description of the key components that a comprehensive and well-organized business plan should contain.

The business plan not only forces the electric cooperative organizers to make sure their proposal is comprehensive and well structured, it also serves as a vehicle for presenting the project proposal to prospective funding sources. The business plan should provide a road map for the development of the project and fully describe the investment opportunity.

The initial incarnation of the business plan is an important early step in the process of forming, funding, and operating a rural electric cooperative. The business plan first aligns project organizers towards the same goals and secondly promotes the project to both the community and lenders. Once the project is funded and built, the business planning process continues. As time goes by and circumstances change so must the way the electric cooperative responds and takes charge of its future. Project leaders capture the changing strategy of the electric cooperative in regular updates to the business plan. The continual cycle of business planning allows for new ideas and renewed coordination and enthusiasm.

A comprehensive business plan for development of a new rural electric cooperative or a new utility with another institutional form should consider all the institutional, organizational, financial, and regulatory issues and steps required for startup and operation. This includes the organizational structure of the institution, plans for management and staffing, power supply procurement, and engineering solutions for distribution line design and construction, financial analysis based on estimates of operating costs and revenues, and regulatory procedures for registration, licensing, retail power tariffs, etc.

If successful, the initial business plan results in the actual implementation of a new electric cooperative. This module provides a suggested format for the business plan and discussion of each key content component. The suggested format includes an executive summary and 10 major sections. The names and order of the business plan sections can change, but this is the same content required in any complete business plan.

The 10 business plan sections are as follows:

1. Project History and Overview
2. Market Analysis
3. Power Supply
4. System Design
5. Management Plan
6. Operational Plan
7. Marketing Plan
8. Regulatory Approval
9. Financial and Economic Analysis
10. Project Implementation

The business plan should provide a road map for the development of the project and fully describe the investment opportunity.

The section of this module on each business plan component describes the purpose and salient content of that component, along with a summary box reminding the reader of key points and a suggested number of pages to dedicate to the topic. As part of a project financed by the United States Trade and Development Agency (USTDA), NRECA prepared a comprehensive business plan for a rural electric cooperative distribution utility in Yemen that illustrates and provides ample detail on each of the sections of the business plan. The full business plan can serve as an illustrative companion to this module.[1]

Rural electric cooperatives are typically formed in response to a community need for reliable and affordable energy.

Although a major objective of the business plan is to attract investment financing from international development agencies and/or the private sector, experience dictates that a business plan alone rarely accomplishes this goal. Skillful promotion of the project and business plan is also necessary. Project organizers should establish a personal link to the community and the project by hosting site tours, generating community enthusiasm, preparing project summaries and presentations, and seeking local financial support for the project.

PURPOSE OF A BUSINESS PLAN

Rural electric cooperatives are typically formed in response to a community need for reliable and affordable energy. An effective business plan can help meet that need.

A business plan forces the project stakeholders to make sure that the business opportunity is well thought out. It also serves as a vehicle to communicate the proposition to potential lenders and other project supporters. A well-structured project, communicated effectively through a detailed business plan, increases the chances of funding and operational success.

[1] See "Ibb Rural Electric Cooperative Business and Institutional Plan" available from the USTDA Library.

Starting any business requires estimating costs and income and projecting cash and other resource needs. This is equally true for profit and nonprofit ventures, including rural electric cooperatives or utilities. The questions that must be addressed include:

- Who will organize the electric cooperative?
- How will the electric cooperative be staffed and managed?
- Where will the power come from?
- Where will the money to build it come from?
- How much will the electricity cost?
- How much electricity will customers purchase?
- Will income cover the costs of operating the electric cooperative?
- What government laws and regulations apply?
- What steps need to be taken and when?

The business plan answers all these questions and more in a formal document. This module provides a description of each major section typically found in a business plan for a new rural electric cooperative.

In some communities, local individuals may have already stepped forward to organize the effort without any plan at all. Such entrepreneurial leadership has high value. However, electric system infrastructure is expensive and investment is needed to supplement the funding capacity of the local community. At some point, prospective investors will require a business plan for due diligence (the determination of lending risk).

THE BUSINESS PLANNING PROCESS

"*The general who wins the battle makes many calculations in his temple before the battle is fought. The general who loses makes but few calculations beforehand.*" – Sun Tzu

This quote from the classic military treatise, The *Art of War,* carries significant business wisdom. Few ventures succeed without careful planning and hard work. Bringing electricity to a rural community is no exception. Drafting a business plan is an early step for any new venture, even when the project organizers have significant business, or perhaps even electric cooperative, expertise. In fact, the more experience the businessperson has, the more likely he or she is to recognize the importance of early and continued planning as an ingredient of success.

The preparation of a good business plan is the responsibility of the project planners. However, they must consult various experts to obtain the analyses upon which they base the plan. The process demands a high degree of focus and a thorough understanding of the proposed venture. Developing a business plan forces the project organizers to answer all the relevant questions of how the business will be formed, funded and operated. Inevitably, this process reveals subtleties, if not significant aspects of organization and implementation, that were overlooked before the formal planning began.

Business planning also aligns project organizers towards the same goals. Verbal communication can allow for multiple interpretations, but a clearly written business plan leaves little room for misunderstanding. The business plan also helps promote the new electric cooperative to the community and is always required by lending agencies.

Each prospective lender is likely to have particular requirements for the business plan format or content. However, the components described here cover the major requirements of most electric system lenders. In promoting the project to lenders, organizers should expect numerous questions. Answering them may require additional analysis or revisions to the business plan. No matter how good the plan, such questions and answers are a normal part of the lender due diligence process.

The business planning process does not end once the project is operating. Like most plans in life, as circumstances change, the plan too must change. The electric cooperative should update its business plan every three to five years, unless major events or opportunities suggest earlier revision. This continual cycle of planning provides an opening to inject new ideas, to adjust strategic direction, to coordinate among employees and stakeholders (those with an interest in the electric cooperative's success), and to keep the business fresh and moving forward in a spirit of service and innovation.

Drafting a business plan is an early step for any new venture, even when the project organizers have significant business, or perhaps even electric cooperative, expertise.

COMPONENTS OF A BUSINESS PLAN

The electric cooperative business plan provides a road map for the successful structuring and funding of the project. While section headings or their ordering can change, a good business plan presents all of this important information in a clear, concise and logical format. A good target size for the document is 25-35 pages (including tables), plus attachments supporting the analyses. Specialized backup information, such as worksheets, detailed assumptions, detailed tables and the like may be gathered into a project file apart from the business plan and made available to interested persons.

Remember that the business plan is not a theoretical exercise but a blueprint for the actual creation of the new electric cooperative. A well-written and practical plan helps to convince stakeholders, including prospective lenders, that the project is viable and that the project sponsors have adequately evaluated risks, revenues, costs, and return on investment for the project.

After each component of the business plan below, a box shows the target number of pages for that section, along with a summary of key points to remember for that component.

Executive Summary

The business plan must document the justification for the project – its history and the local context that created the need for the project.

As the name indicates, the Executive Summary is for those who may not have time to read the entire plan and require a quick yet comprehensive understanding of the scope of the project, the investment required, projected returns, and project risks. The target audience for this section includes executives from prospective lending institutions, policy makers, and community business leaders. This section of the plan can also be printed separately later for distribution to supporters and local media as a part of a community awareness campaign.

The Executive Summary must succinctly summarize the entire plan in just one or two pages. That is a lot of information to condense, and great care must be taken to use words sparingly and describe only the most salient points of each section in the business plan. There are two keys to making this work. First, write the Executive Summary last. Second, summarize only the highest-level points from each section of the main document. This may mean one brief paragraph or even just a series of bullet points for each of the 10 major sections of the business plan.

For instance, in the body of the business plan, the section on distribution system design contains significant detail describing electrical load analysis, area geography, substation location and sizing, line construction, and costs. In contrast, the paragraph in the Executive Summary on distribution system design need only summarize the most salient points. The following example from a business plan for a rural electrification project in India shows just how simple and concise such a summary can be:

The distribution system will include a single 15 km 33 KV line and substation located near Sonakhali, with 110 km of three phase line and 75 km of single-phase line distributing power throughout the service area. The distribution facilities and capitalized project costs will total just over US$3 million.

Target Length

- 1 to 2 pages maximum

Key Points

- Write the Executive Summary last.
- One paragraph for each major section of the plan.
- Summarize highest level points only.

Project History and Overview

Some of the people who read a business plan will have little or no knowledge of the project background and the community it serves. Therefore, the plan must document the justification for the project – its history and the local context that created the need for the project. The project history and overview section also makes the project intelligible in a broader economic and social perspective. It should include an overview of the project's scope and its current status of development.

Once readers are informed of the project purpose and the characteristics of the communities that will benefit from it, it will be easier to describe the broader goals and objectives. This section of the plan is the first opportunity to explain the path already traveled and the project's goals for the road ahead. Include basic background issues, such as:

- Location of the project and area geography
- Area population and demographics, including socioeconomic data, employment and poverty

- Nature of the economy, industry and natural resources
- Sources of energy currently utilized
- Past attempts to improve or start an electric system
- Why, how, and by whom the current effort is organized
- General scope of the project
- Accomplishments to date and status of the project

This section is also a good place to introduce any major complexities of the project, especially cultural, political, legal, or other factors or issues that may either pose hurdles (e.g. past failures) or facilitate the project (e.g. new laws). Include all topics that are essential to understanding the project and to forming a judgment about it. While a particular issue might be addressed in depth later in the plan, if it is significant, introduce it briefly here. For a significant obstacle or challenge to project implementation, present not only the problem, but also options that might solve it.

The project history and overview serve not only to educate outsiders and prospective lenders, but also to refresh and realign fellow organizers, the community at large, and ultimately, employees of the electric cooperative.

Target Length

- 1 to 3 pages

Key Points

- Establish project background, local conditions and socioeconomic context.
- Describe project scope and current status.
- Introduce any major contextual issues and solutions.

Market Analysis

In this section, the business plan becomes more analytical. Prospective lenders need to know that all aspects of the business have been objectively analyzed and that the project is viable. Analysis begins with the market. The goal of the market analysis is to estimate the demand for electricity – how much electricity the cooperative will sell and at what price.

For the market analysis section of the business plan, include the projected number of customers, by category (residential, commercial, industrial); the average expected monthly usage per customer (in kWh); and the price per unit of sales, by category (price per kWh).

The goal of the market analysis is to estimate the demand for electricity- how much electricity the cooperative will sell and at what price.

In areas where the electric cooperative will serve a newly electrified community (or communities) a willingness-to-pay survey and economic benefit analysis is normally a required part of market analysis (for more information please see Module 6 – *Consumer Willingness-to-Pay and Economic Benefit Analysis of Rural Electrification Projects*).

All estimates should be segmented by customer category and based on analysis of likely behavior, energy requirements, and alternative energy sources available. Along with presenting estimates of the initial demand, provide a long-term (usually 10-year) projection of demand based on data concerning population growth trends, industry risk, and other factors. As a general rule, provide enough evidence in the plan to show that the market estimates are sophisticated, but do not provide an overabundance of detail. Present a table summarizing the initial and long-term demand. Supporting documentation can be provided as an attachment or made available in a project file during the due diligence process, if requested.

Target Length

- 2 to 4 pages maximum

Key Points

- Estimate electricity sales using a "ground-up" approach.
- Analyze components and segments of the market, growth and risk.
- Include a table summarizing the initial and projected market.

The project must show the availability, at affordable cost, of sufficient power to meet the initial energy and demand requirements of the system and allow for system growth.

Power Supply

The important question of where the project will obtain electricity is answered in this section of the plan. Power sources include (individually or in combination): grid connection(s), local generation (fossil, renewable, biomass), and excess industrial cogeneration. Whatever the particular situation, the project must show the availability, at affordable cost, of sufficient power to meet the initial energy and demand requirements of the system and allow for system growth.

Project energy requirements are equal to the total kilowatt-hour (kWh) consumption (per unit of time – day, month or year) of all customers connected to the system, plus estimated distribution line losses. The demand requirement is the simultaneous, highest (or peak) demand for power on the system by all customers, as measured in kilowatts (KW), plus a factor for distribution losses. It represents the maximum generation supply that must be available to meet daily and annual peak electricity use. The rural electric cooperative should size its own power generation and/or contract for power purchase accordingly.

As for the power supply, there must be both sufficient capacity of installed power generation to meet peak demand and sufficient transmission capacity to distribute that power to the customers. If restrictions exist, the power supply plan must identify solutions that indicate whether the cost of a new generation plan or transmission line is to be borne by the power supplier or the distribution system.

Grid-connected projects usually employ existing transmission and generation capacity, but it may be necessary to expand capacity if the project under consideration may overburden the power system to which the new project will be interconnected. Alternatively, some or many projects under consideration may require isolated power generation and distribution systems, especially if grid resources are distant and interconnection is not economically viable. Whether expansion of capacity involves expanding the existing generation and transmission system or building new isolated power generation and transmission capacity, project planners should perform an analysis of power generation and transmission capacity that evaluates these resources over a 15 to 20-year time horizon.

The business plan should describe the power generation resources and provide a photograph of the power plant in the case of local generation. It should also include a single-line diagram of the transmission path and delivery point. Also present the cost of power, along with salient details on pricing structure and minimum commitments from the power generation company for energy quality, price, and availability.

If the power supply resources are not owned by the project, then the agreement concerning the delivery of power to the project, including pricing and financial terms, should be referenced in this section of the plan. The business plan is much more persuasive if such agreements (known as power purchase/supply agreements) are already fully negotiated. Lenders want assurances of the reliability (financial as well as technical) of the power supplier. A contingency plan for alternative or additional power sources would be ideal, but is often not an option, especially in rural areas.

Target Length

- 2 to 4 pages

Key Points

- Present power source and transmission supply.
- Identify initial and future power requirements.
- Describe pricing and other financial terms, along with reliability of supplier.

Distribution System Design

This section of the business plan presents the electrical design of the distribution system. Prepared by professional electric distribution design engineers, the electrical load analysis and engineering solution is normally a report in itself, which is referenced in the plan along with a summary of key characteristics of the distribution system design and cost. See Module 7, *Distribution Line Design and Cost Estimation for Rural Electrification Projects*, for information on how to create the engineering report referenced in the business plan.

The distribution system is designed to receive power from the supply source and transmit it via medium or low-voltage distribution lines, to consumers throughout the service area. Often, the distribution system design includes a multi-phase construction plan, as increased capital investment and/or increased electrical load make expansion economically viable.

Inserting a high-level electrical diagram of the proposed system (one page) in the business plan is helpful. It may also be appropriate to insert a more detailed schematic in an appendix. The description in the business plan should include the main system facilities: grid substations, distribution substations, and main feeders, along with the length of extensions and lateral lines to reach the optimal number of initial customers.

Since those who will review the business plan are likely to have seen systems of greatly varying quality, establish the engineering and construction standards used in the project design. These standards set project targets regarding component life, safety, energy loss optimization, regulatory compliance, and reliability. Standards include, but are not limited to, industry standards and best practices for unitized construction, single versus three-phase lines and transformers, delivery point metering, sectionalizing, and voltage regulation. Investors generally understand the trade-off between the level of investment in capital equipment and recurring costs, where more money spent on better equipment leads to lower operation and maintenance expenses.

The business plan should also include a schedule of major system components, the number of units required, and their cost. The cost of these items, together with the estimate for engineering and construction, represent the initial cost of the system. The total cost includes other items, such as working capital, capitalized development costs and interest, and contingencies, which are part of the financial analysis of the project.

Target Length

- 4 to 6 pages

Key Points

- Present key characteristics of distribution system design, in phases if appropriate.
- Describe main system facilities and include a diagram of the electrical system.
- Include a schedule of major components and costs.

Management Plan

This section of the business plan communicates the organizational and management structure of the project. Typically, the electric cooperative fully

The distribution system is designed to receive power from the supply source and transmit it via medium or low-voltage distribution lines, to consumers throughout the service area.

owns the project. However, any joint ownership or lease arrangement must be described.

The electric cooperative's organizational documents (articles of incorporation and bylaws) should ideally be in place prior to finalizing the business plan. If they are not, reference drafts of those documents. These organizational documents are typically not attached to the business plan, but are made available for review during due diligence. Describe any requirements for business registration with government authorities and note the status.

The electric cooperative's organizational documents (articles of incorporation and bylaws) should ideally be in place prior to finalizing the business plan.

The governance of the electric cooperative is explained in this section of the plan: the structure of the Board of Directors, membership requirements, and voting rights, provisions for audit, other board committees, and arrangements for legal representation. Mention of specific outside audit and legal firms, if already identified, is helpful, as this adds credibility to the plan, especially if they are recognized regionally or nationally.

The Board of Directors is charged with governance and setting institutional policies, and is also charged with hiring management. Together with senior management, the Board sets strategic direction, the execution of which is the responsibility of management. Management is responsible for execution of board policy, overall direction of day-to-day activities, and implementation of long-term goals and objectives. It is also responsible for recruitment and retention of qualified staff to administer and operate the electric cooperative. A discussion of the chain of command and division of responsibilities should appear in this section.

Some functions might be outsourced to facilitate startup, or permanently, as a cost-saving strategy. For example, a local telephone service provider might more easily and efficiently manage billing and collection functions than rural electric cooperative staff. Such arrangements are acceptable, but should be justified by cost savings, and the vendor referenced in the plan.

If planners have already identified senior management, include a brief biography for each person. The same can be done for founding board members and key senior staff, such as the maintenance or crew chief. Summarize all staff requirements in a table showing the position, number of staff, and salary or wage. Briefly reference planned benefit programs as well.

Target Length

- 2 pages

Key Points

- Describe project ownership and organization.
- Explain governance, audit provisions, and legal representation.
- Present biographies on key people; list staff positions and their salaries/wages.

Operational Plan

The operational plan section of the business plan provides the opportunity to describe how the project will operate, showing competence in areas such as:

- Customer inscription and service
- Connections and disconnections
- Meter reading and billing
- Accounting and finance
- Purchasing and inventory
- Maintenance and repair
- Loss control and prevention
- Engineering and planning

This section describes the plan for operating the rural electric cooperative on a day-to-day basis. Handling such a broad topic in just a few pages is a challenge, but the goal is not to create a detailed employee manual, rather just to generate confidence that the electric cooperative has a well-considered and logical operating plan.

One approach is to begin by stating the electric cooperative's operational philosophy, including priorities and targets for issues such as employee training and supervision, emergency response time, inventory levels, supplies and materials quality, cost containment, safety, customer complaints, and system reliability. The operational philosophy establishes a framework for the electric cooperative's policies without the need to describe each operational activity and procedure in the business plan.

However, do describe major programs, according to the priorities of the particular project. For example, in the case of an initial build-out reaching only a small portion of the market, the business plan should describe the operational aspects of member subscriptions and line extensions to reach additional customers. Or, in an area of anticipated high electricity theft, describe the plan for detecting, policing, prosecuting, and preventing loss. Other components of the operational plan, if unique or substantially different than industry standards, should also be mentioned.

Target Length

- 2 to 3 pages

Key Points

- State the guiding operational philosophies.
- Address enough detail to express competence in operating a electric cooperative.
- Describe major programs or thrusts, especially if different from industry norms.

Marketing Plan

Marketing begins with building enthusiasm in the community for project implementation and continues through energization and system expansion. As an ongoing process, marketing is important not only during project initiation, but also for maturing electric distribution cooperatives. A well-defined and conceived marketing plan both retains existing consumers and attracts new consumer connections. While there needs to be a person responsible for the effort, marketing is as much a client-focused attitude as it is a distinct program. Institutional cultures are normally established top-down and from early on, and care should be taken to establish an appropriate culture towards the community that the system will serve.

As with operations, the marketing plan section of the business plan should include a description of the cooperative's philosophy with regard to marketing – that is, the relationship it wants to have with customers, industry and the community at large. The marketing section of the business plan should explain where, within the cooperative, responsibility for this function lies, its funding level, and its initial focus. Typically, in the early days of electric cooperative operation, marketing is the responsibility of the whole staff. Technical, financial, and operations personnel must pitch in on membership drives and customer education, especially in areas never before electrified.

Effective marketing requires understanding the culture, lifestyle, and consumption habits of the community, as well as energy alternatives or competitive products available. Expressing this understanding through a thoughtful description of the marketing effort is the central goal of this section of the business plan.

This section should also establish electricity pricing targets, segmented at a minimum by consumer class. For rate-regulated utilities, the rates may already be established. Otherwise,

Effective marketing requires understanding the culture, lifestyle, and consumption habits of the community, as well as energy alternatives or competitive products available.

the electric cooperative must analyze the cost structure of its power supply and develop a rate scheme that is affordable, considers the pricing of competitive sources, and generates sufficient revenues to cover the cost of operations. Insert a list of the proposed rate structure.

Finally, the marketing plan should anticipate how the program might change focus as the distribution system matures and new needs, hurdles, and opportunities arise. Such changes may include integrating the marketing effort with billing and customer service, or initiating new programs such as loss reduction, incentive tariffs, and equipment sales.

The business plan should describe the regulatory authority, the process for obtaining all required approvals, and provide a status report.

Target Length

- 2 pages

Key Points

- State the philosophy of the rural electric cooperative regarding its relationship with customers.
- Show your thorough understanding of the market.
- Explain and list rates segmented by customer class.

Regulatory Approval

This section applies only to those rural cooperatives subject to regulatory oversight. Regulatory oversight can vary by province and by country. While most countries have at least requirements for electric cooperative business registration, an additional level of regulatory oversight applies in many jurisdictions.

In nearly all countries, the working hypothesis upon which regulatory oversight is based is that electric service is a natural monopoly. That is, it is not economically efficient to have more than a single service provider in an area. Once a monopoly is authorized, it must also be regulated, absent the checks inherent in a competitive market.

The regulatory authority is generally vested in a public utility commission, line ministry (such as a Ministry of Energy or Electricity), or a regulatory board, which has oversight in one or more of the following areas:

- Service territory
- Rate regulation
- Quality of service

Service territories are defined to prevent duplication of investment as well as to establish the boundaries of the electric cooperative's obligation to serve. Within the constraints of its line extension policy, that electric cooperative must serve all interested customers in its territory. This is the quid pro quo in the regulatory compact awarding a monopoly franchise to the electric cooperative.

Rate regulation is the most direct manifestation of the regulatory authority in its role as proxy for a competitive market. It is important to remember that the regulator has an equal obligation to both the customer and electric cooperative. It must be watchful to make sure customers are not overcharged but also ensure that the electric cooperative earns its margins.

Quality of service regulation ensures just that, encompassing electric cooperative response time to customer connection requests and complaints, as well as reliability and power quality.

In the case of regulatory oversight, the business plan should describe the regulatory authority, explain the areas in which the electric cooperative is subject to regulation, describe the process for obtaining all required approvals, and provide a status report.

Target Length

- 1 to 2 pages

Key Points

- Identify areas of regulatory oversight and the relevant governmental authority.
- Explain the approval process.
- Report status to date.

Financial and Economic Analysis

This section of the business plan shows that the project's financial viability has been established through a careful analysis of the project's costs and benefits. The analysis most often employs a computer-based model to compare the project's cash receipts against its cash outflow. Typically, financial projections for electric utilities are modeled over a minimum 10-year horizon. The analysis should use the most reliable data obtainable.

One of the most important steps in applying a financial model – and presenting the results in the business plan – is stating all major assumptions and parameters. These include the construction and system build-out periods, terms on project debt, sales growth, electricity rates, cost of power, operation and maintenance expenses, and line and technical losses. Take care to have good supporting data and justifications for all major assumptions.

The financial model produces detailed projections of income, cash flow, and sources/uses of funds statements, along with indicators of project viability and attractiveness (such as internal rate of return and cash return on equity). The model should analyze multiple scenarios, testing the impact of changes in key variables on the bottom line (sensitivity analysis) or identifying the values key variables must hold in order for revenues to cover costs (breakeven analysis).

The output of the financial model is often included as an attachment to the business plan. Summary tables and accompanying narrative should appear in the body of the document and describe central findings, addressing key items such as earnings, cash flow, investment return indices, and project risks. For marginal projects, the analysis should show that the project generates sufficient cash to service debt and fund depreciation, and if not, describe the level of subsidy required to achieve feasibility.

Typically, financial projections for electric utilities are modeled over a minimum 10-year horizon.

Some lenders also require an economic analysis of the project. While a financial analysis takes the viewpoint of the individual participants and estimates the financial effects of the project on them, an economic analysis takes the viewpoint of society as a whole, estimating the benefits of the project to the economy. Both use measures of discounted cash flow, but they define and value costs and benefits differently. For example, taxes are not treated as costs in the economic analysis, but subsidies are. With the above-mentioned items in mind, plan on performing only a financial analysis for the business plan. If debt or subsidy providers require an economic analysis, perform it using an accepted methodology.

Target Length

- 2 to 5 pages

Key Points

- Perform financial model projections for 10 years and an economic analysis if requested.
- State all major assumptions and have supporting justification on hand.
- Insert a table and describe key results, including project returns and risks.

Project Implementation

Now that the project has been fully presented, engineered, and analyzed, the final section of the business plan lists and explains the concrete actions to be taken to implement the project. This is an opportunity not only to think through all the implementation steps, but also to demonstrate to the reader that the electric cooperative knows how to bring in the project on schedule and within budget, while meeting customer connection targets.

The section itself can be formatted in multiple ways, but it is always a good idea to insert a list or chart of steps and milestones planned for project implementation. A Gantt chart (a bar chart showing how all the required tasks progress, over time and with respect to each other) is often useful for this. As with most complex projects, many of the tasks overlap, and the Gantt chart is a handy tool to communicate this graphically.

Typically, the project implementation schedule focuses on the construction period, defined as the period beginning with funding and ending when the electric cooperative is energized. At this point the electric cooperative should be functioning as detailed in the operation plan. Include in this section a list of key project tasks, assignment of responsibilities, and realistic estimates of task completion times.

Equally critical is the identification of an overall project manager, ideally an individual or firm that has completed many similar assignments. If a construction firm is already identified, briefly present its experience. Project and construction management could be one and the same, depending on the size and complexity of the project.

The project implementation schedule should extend at least until system energization. If the project has phases, or a significant build-out remains after the initial project construction, then the schedule should also include subsequent customer connection milestones. The expected timing of sales and cash flow, as well as expansion costs, is more appropriately covered in the financial model discussion.

Target Length

- 1 to 3 pages

Key Points

- List concrete steps and demonstrate the ability to execute them.
- Insert a Gantt chart or other graphical representation of steps.
- Show responsibilities, completion targets, and key project milestones.

PROMOTING THE BUSINESS PLAN

Many an entrepreneur and project organizer has learned that a well-written business plan alone rarely raises money. Numerous factors contribute to a funding decision and, while it is an absolute necessity, the business plan is only a part of the process that culminates in the completion of the project.

Although the engineering must be solid and the financial projections viable, lender support of a project is as much about faith in the project organizers and the local community and economy as it is about technical factors. The better the project team can establish a personal link between lenders and the community, the more likely are the chances of success.

The better the project team can establish a personal link between lenders and the community, the more likely are the chances of success.

This means that dedication to the project, local enthusiasm, and community support all count. Be sure to make this support evident through careful advance planning for site visits by lenders. Prepare community leaders by educating them fully about the project and its benefits to the community.

Dedicate and train a two or three-person contingent from the project organizational team to host visiting consultants and prospective lenders. Depending on local facilities and equipment availability, a PowerPoint presentation is a good way to orient the visitors upon arrival. Limit it to 10 slides and 20 minutes for best results.

Plan ahead for all stops along the tour route. Include visits with future customers, small and large, and allow time for separate conversations with any sizable industry that may exist in the area. Industry or not, it is important to demonstrate that the service area has an underlying stable, if not growing, economy.

Utilize the Executive Summary from the business plan (as is or modified for public consumption) as a tool to create local enthusiasm for the project. It can also provide talking points for community meetings, be distributed in flyers, and be circulated to any local and regional media (radio station or newspaper).

Also, create a 3-5 page project summary that can be utilized to interest prospective lenders in the project. Until initial interest is aroused, lenders are unlikely to take the time to read the full business plan. If the business plan interests a prospective lender, the next step is the due diligence process, when clarifying questions are asked and revenue and cost estimates verified. All supporting studies, facts, and figures should be readily available so as to provide a quick and comprehensive response to due diligence requests.

Finally, while not always possible, there is nothing better than local financial support to provide comfort to an outside lender. Even if they are small in amount compared to the funding target, local monetary commitments by future customers, industry, or lending institutions carry a big and positive message to prospective project financiers.

While not always possible, there is nothing better than local financial support to provide comfort to an outside lender.

Methodology for Evaluating Feasibility of Rural Electrification Projects

MODULE 5 OF NRECA'S TECHNICAL ASSISTANCE GUIDES

5

EXECUTIVE SUMMARY

Developing a well-designed, sustainable rural electrification project is one of the biggest challenges faced by governments and electric service utilities in developing countries. While providing public services to rural communities is increasingly important, rural electricity projects typically display a relatively high investment cost and low rates of consumption.

Very few countries have experienced success in establishing financially and economically sustainable programs. One of the primary obstacles is establishing logical and transparent mechanisms for the selection and analysis of feasible projects. At a minimum, electrification projects, like other infrastructure investments, must position themselves to recuperate operating costs. The operating costs include the cost of purchasing (or producing) energy, system operations and maintenance costs, and the costs associated with the depreciation of fixed assets. Without recuperating these costs, an electrification project would need continued financial support to sustain operations.

This module presents a quantitative evaluation methodology for institutions and professionals engaged in designing and implementing rural electrification programs and projects. The methodology includes all elements of project design and analysis, particularly for the extension of grid-based distribution systems. In addition, the methodology describes the concepts, objectives and practical steps required to evaluate technical viability and financial sustainability, including a process to evaluate capital subsidies, should they be required. Towards this end, the module walks the reader through seven steps in project definition, design, and analysis.

1. *Project identification.* The first step determines the geographic scope and the technical and economic conditions of the project so as to analyze and determine whether the necessary conditions exist to proceed with subsequent studies.

2. *Demographic analysis.* The demographic study establishes the market conditions of the project, defines the number and type of beneficiaries, and identifies uses of the to-be-constructed electric system. The analyst carries out field surveys to compile the necessary information. Among the most significant information obtained is data regarding the project beneficiaries' capacity and willingness to pay. This information determines the project beneficiaries' relative economic activities and levels, which indicates whether or not they can afford the tariff set by the electric service company. In addition, the data enable the analyst to calculate the quantity and percentage of consumers who may connect to the electric distribution system during its first year of operation and in subsequent years thereafter.

3. *Preliminary project design.* At this point, the analyst defines the basic structure of the proposed electric grid, as well as the lengths and positions of the medium to low-voltage lines, using geo-referencing instruments such as a Global Positioning System (GPS) device. This "virtual staking" technique helps determine project feasibility and eliminates the pre-investment costs of having an engineer walk the proposed path of the line.

4. *Demand determination.* Next, the analyst defines the quantity of energy and power

Electrification projects must position themselves to recuperate operating costs. Without recuperating these costs, an electrification project would need continued financial support to sustain operations.

that the project requires, taking into account consumption by consumer classification, consumer penetration rates, consumer growth rates, consumption growth rates, energy losses, and public lighting. This information serves as the basis for energy purchase (or production) calculations. This step also provides data subsequent analysis of the revenues generated from the energy sold to the potential beneficiaries of the project.

Rural electrification projects can yield high socio-economic (non-cash) returns to the community members they serve, including the reduction of traditional energy costs, as well as health and educational benefits.

5. *Engineering analysis and costs determination.* Here the analyst defines the technical characteristics and conditions under which the project will be constructed. These characteristics define the total costs that the project will incur, in addition to determining the selection of components and equipment to be utilized.

6. *Economic analysis.* This step quantifies the benefits the project will yield for the community it serves. Generally, rural electrification projects require capital subsidies, due to their relatively high capital cost in relation to a relatively low expected revenue stream. However, rural electrification projects can yield high economic (non-cash) returns to the community members they serve, including the reduction of traditional energy costs, as well as health and educational benefits.

7. *Project feasibility analysis.* Finally, financial analysis measures the financial feasibility of the project, evaluating the relationship of the project's revenues in relation to project costs. A financial model for the project measures financial costs and benefits, normally employing a spreadsheet to model the net revenues over a specific project time horizon. The financial analysis determines the profitability – or the losses and costs – of the proposed project. To identify the most feasible project option, analysts use two analysis methodologies: bandwidth and sensitivity analysis. The results of the financial analysis are summarized, in part, by several well-known investment recuperation indicators, such as Return on Equity (ROE) and Internal Rate of Return (IRR). These indicators compare the net present value of the revenues and expenses over a set time period. In addition, in cases where the results of these indicators are negative, project planners can analyze the justification for a government subsidy. Since governmental subsidies often cover investment costs, they can be justified when the social benefits are greater than the social costs.

A case study provides a practical illustration of the various analyses presented in this module. The sample project is a rural electrification project implemented in Potosí, Bolivia, referred to as the Tomoyo project.

INTRODUCTION

Rural electrification is a key component of national economic development efforts. It is a challenge requiring consideration of many technical, economic, demographic, and financial factors. Communities require access to electricity to improve their quality of life, and to offer improved health, education, and potable water. However, not all communities have the financial resources to pay the full cost of modern energy services. In most developing economies, a majority of the rural population operates in a highly precarious economic environment.

Traditionally, economically marginal communities do not represent an attractive market for private utility investors. Compared to potential electricity sales, the cost of electric service for marginal, rural communities is a stumbling block for many project developers. Rural communities traditionally have a low energy demand, which implies a high cost of service, coupled with a relatively low ability to pay for electric service. This naturally implies that the market cannot sustain private commercial investments without government assistance.

A role of government is to appropriate limited public financial resources in a manner that assures transparency and objectivity in the prioritization and selection of projects with a reasonable potential to succeed. This implies that projects must be sustainable and designed to maximize economic impact. Therefore, the government institution or agency responsible for rural electrification programs must compile the necessary data to define the rural electricity market, identify projects with potential, analyze the feasibility of such projects, and elaborate a suitable investment program. This module provides an important tool in the execution of this process.

This module describes a methodology to evaluate the costs, estimate the benefits, and analyze the feasibility of electrification projects in an efficient manner. As any project developer knows, a rigorous but practical and accessible methodology to categorize projects is an indispensable tool in defining investment priorities objectively.

This module presents concepts, terms, and methodology for wide application. Its target audience includes economists, engineers, consultants, and professionals involved in the elaboration of electrification projects. It should be a useful tool for experienced engineers and economists, as well as for people just beginning their careers in the field of feasibility analysis for rural electrification.

Essential Definitions

The material presented in this module will be easier to understand and apply if some key definitions are established. The following list of concepts and their respective definitions are commonly used in this module:

- *Economic analysis:* calculates the benefits generated by the project for the community affected by the project. Economic benefits result from the technological substitution of energy sources used by the project, the reduction of costs linked to the introduction of new technology, and the increase of services resulting from new technology.

- *Financial analysis:* a method for evaluating and reviewing scenarios to determine the most viable system design for the community and for estimating the overall financial viability of the project.

- *Energy alternatives:* candles, kerosene, batteries, solar panels, and other energy sources used as sources of energy in the absence of modern distributed electric services.

- *Demographic study:* the study of the characteristics of communities and their members within a defined project area. It determines the communities' cultural, economic, and social characteristics in relation to the objectives of the project under consideration.

- *Demand study:* analyzes the average monthly or annual energy consumption for each consumer category, the expected power demand resulting from energy consumption estimates, and the growth rates and net consumption or power growth over the project time horizon.

- *Willingness to pay:* an assessment of the amount that consumers are now paying for electric and non-electric energy services, as well as estimates of the "expressed willingness to pay" for energy services, using a carefully defined auction or bid survey methodology.

Organization

This module presents a quantitative evaluation methodology for designing and implementing rural electrification programs and projects. The methodology includes all elements of project design and analysis, particularly for the extension of grid based distribution systems. The methodology describes the concepts, objectives, and practical steps required to evaluate technical

A role of government is to appropriate limited public financial resources in a manner that assures transparency and objectivity in the prioritization and selection of projects with a reasonable potential to succeed.

viability and financial sustainability, including a process to evaluate capital subsidies – if they are required. Towards this end, the module walks the reader through the following seven steps in project definition, design, and analysis:

1. Project identification
2. Demographic analysis
3. Preliminary project design
4. Demand determination
5. Engineering analysis and costs estimation
6. Economic analysis
7. Project feasibility analysis

A specific rural electrification project, designed and executed by NRECA in Potosi, Bolivia (referred to as the Tomoyo Project) appears as an example throughout the module to provide contextual background information for the concepts being explained.

PROJECT IDENTIFICATION

Each electrification project involves a specific geographic area and serves a specific group of rural communities or housing clusters. The geographical limits of a rural electrification project relate to factors such as the distance between the project's energy source and the community, the distance to the existing electric grid, the distances between communities, the electric demand of each community, and the estimated maintenance requirements envisioned during the life of the project. These factors have an important impact on the project's implementation and operating costs. The project must present economies of scale to be able to serve sufficient energy demand, and thus collect sufficient revenue, to cover operating costs, in the face of factors like the physical characteristics of the area, the number of consumers, etc.

Definition of the Scope of the Project and Information Compilation

Project identification consists of defining the project's scope and geographic location, as well as compiling the target area's market data, economic characteristics, and the energy options. The first task within this process is defining the geographic location and physical scope of the project. Keep in mind that grid line extensions are often built adjacent to roadways to facilitate line construction and line maintenance. Roads facilitate and permit the service provider to attend to its customers, verify consumer data, and collect for services rendered, eliminating overbearing logistical and transportation difficulties.

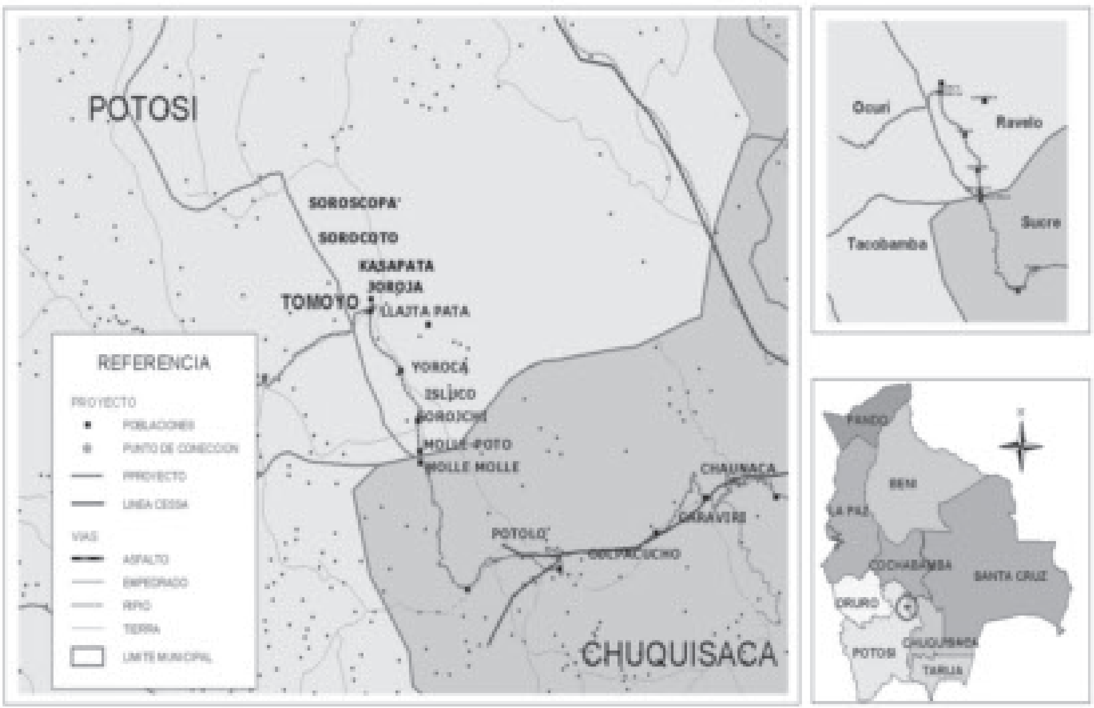
After defining the project area, the gathering of demographic and infrastructure data starts, along with the organization of the analysis process. Most project data, especially data containing spatial attributes, are organized using geographic maps. With the recent advent of GIS, it has become more common and practical to organize data in electronic, geographically referenced data systems. Information on the use of GIS appears later in this module.

Conventional project maps should present cartographic, technical, political and geographic attributes of the project area. Many of the variables involved in electrification feasibility studies contain a spatial component. For example, electric lines are normally located in close proximity to all-weather roads.

Figure 1 presents the geographic characteristics of the Tomoyo project.

Other data that should be included and compiled in project databases include the number of communities, which municipality they are in, the number of inhabitants per community and in total, and the number of un-electrified homes in the

Figure 1. Geographic location of the Tomoyo project



project area. The project analysis database should include fields for community names, number of inhabitants in each community, community income levels, and monthly energy consumption. Census data, if available, can be an important data source that should be investigated. However, if a census is over five years old, the analyst should search for other, more up-to-date data sources.

Table 1 presents an overview of the project database for the Tomoyo. It includes community location, political boundaries, number of homes, and distances between communities.

To geographically reference the attributes of the database with the project area maps, a unique identifier must be established. Normally, this would be the name of the village or community. However, sometimes communities share the same name. In such cases, establish a data field containing a code that provides an alpha-numeric representation for each community, linking the data in the database with its corresponding geographic data managed through a geographic information system.

A GIS offers a more efficient way of organizing and managing geographic information. The GIS platform relates physical, technical, demographic, and natural resource information in a geographic framework. It allows the user not only to store data, but also carry out numerical, algebraic and statistical analysis, as well as create computation programs within the same GIS. GIS is a potent tool for the development of rural electrification programs, but it requires a greater financial and human resource investment. For this reason, it has been underutilized in planning a majority of rural electrification programs. Nonetheless, it remains a powerful and flexible tool for evaluating single or multiple electrification projects in a dynamic and interactive format.

Project Energy Source and Supply Options

Historically, various energy sources and supply technologies have been employed in successfully completed electrification projects. However, the financial resources of the project and the physical characteristics of the project area contribute to or

GIS is a potent tool for the development of rural electrification programs, but it requires a greater financial and human resource investment.

Table 1. Database for the Tomoyo Project

Community	Department	Province	Municipality	No. Homes Secondary Data	No. Homes Field Surveys	Distance between Communities
Molle Molle (Chuquisaca)	Chuquisaca	Oropeza	Capital Sucre	54	54	6.4
Molle Molle (Potosí)	Potosí	Chayanta	Ravelo	160	146	6.4
Sorojchi	Potosí	Chayanta	Ravelo	105	105	2.7
Yoroca	Potosí	Chayanta	Ravelo	90	98	2.5
Tomoyo	Potosí	Chayanta	Ravelo	95	114	4.2
Llajtapata	Potosí	Chayanta	Ravelo	60	50	2
Isluco	Potosí	Chayanta	Ravelo	100	30	2
Jiroja	Potosí	Chayanta	Ravelo	70	60	1
Kasapata	Potosí	Chayanta	Ravelo	60	50	3
Sorocoto	Potosí	Chayanta	Ravelo	160	160	3.5
Soroscopa	Potosí	Chayanta	Ocuri	60	60	1
TOTAL				**1014**	**927**	**28.3**

Well-designed projects focus on the selection of energy sources that minimize the operational costs of the service provided, in balance with the project's environmental and social benefits and costs.

may limit technology and resource options. For example, the extension of an electric distribution grid to an un-electrified community depends upon the distance from the community to the nearest interconnection point for a grid substation. Note that distance includes not only horizontal distance but also vertical distance, in that hilly terrain requires more kilometers of line and more poles to connect a community to the grid. Similarly, if grid interconnection does not appear viable, and natural gas resources are available, the analyst must take into account the distance to a natural gas distribution network. In addition, resource surveys are required if the project developer wishes to consider renewable energy resources for energy generation, such as wind, hydropower, solar, and/or biomass energy.

Although renewable resources have low operating costs and high environmental benefits, the analyst must keep in mind two key variables for each electrification project: the project energy requirements, and the cost of installing and using renewable technology. For a project to be viable, the renewable resource must be able to satisfy energy demand at a cost of delivered service that is competitive with conventional energy delivery options and consumer willingness to pay. Well-designed projects focus on the selection of energy sources that minimize the operational costs of the service provided, in balance with the project's environmental and social benefits and costs.

For each geographic area, options are normally limited to the specific resources available within a serviceable distance from the target communities. Not all projects have sufficient wind, hydropower, or biomass resources to consider employing these energy options.

In some cases, hydropower resources may be located within a serviceable distance from the target community. However, there is no linear relationship between distance and load. The hydrological seasonality of the site plays a significant role in its viability for remote power generation. Without a nearby interconnection point with a distribution or transmission grid, project planners must perform a preliminary site evaluation to determine it's the technical and financial viability of hydropower. The preliminary evaluation will be based upon stream flow data, estimated head (i.e., the vertical drop between the system's forebay tank and powerhouse), cost estimates for turbo-mechanical and electrical machinery, as well as cost estimates for site preparation and civil works. In addition, the preliminary analysis must consider power and energy analysis, the energy demands of the community, seasonal fluctuations in stream flow, and costs for operation and maintenance of the system.

Several projects have successfully initiated biomass power generation in selected rural electrification schemes. The biggest challenges encountered relate to the costs associated with transporting the biomass to the conversion site and generating sufficient energy to offset the cost of the boiler and generator infrastructure. Where sugar refineries, rice and/or oil mills, or other agricultural processing plants exist, their processing centers may have sufficient size and be capable of generating the quantity of biomass needed to justify a biomass conversion/generation plant. Normally, the minimum power plant capacity for this technology option is around 1,000 kW. Under normal circumstances, this is sufficient to generate electricity at a price below $ 0.10/kWh.

Solar photovoltaic (PV) energy technologies have found success in various projects worldwide. This technology is well known, and exploitable in applications for illumination, water pumping, electrification of isolated health clinics, schools, etc. The system is very simple, and requires relatively little maintenance. A basic system includes a solar PV array, lead-acid battery, charge controller, usually one or two service outlets, and two or three lamps. Because PV system cost varies linearly with energy demand, its use is ideal where energy consumption is limited to lighting and basic entertainment systems. Moreover, solar photovoltaic energy systems do not create any economies of scale. However, for rural electrification projects consisting of dispersed non-electrified rural homes, with a low potential for productive uses of electricity, solar photovoltaic systems may turn out to be least-cost technology alternative. See Module 10: *Design and Implementation Guidelines for Stand-Alone Photovoltaic Systems for Rural Electrification Projects* for more information.

Wind turbines are another generation option for rural electrification. Wind turbines require relatively high wind velocities to operate effectively. Winds speeds normally need to be greater than 4 meters per second for small-scale systems and greater than 7 meters per second for larger-scale systems. Either these systems are designed to feed into an electric grid, or the system is configured as part of a hybrid energy system– combining the wind turbine with another generation technology, such as a diesel generator and battery bank. Wind systems, similar to other renewable energy technologies, are often subject to seasonal variation in generation output, challenging long-term project sustainability. The analyst must balance the variable generation pattern of the technology chosen with the need to meet base and peak load demands of the system.

Hybrid wind systems are relatively complex and costly. In addition, they can present significant management risks due to their relatively high maintenance requirements. However, when considering overall project financial feasibility, wind-hybrid systems bear consideration, among others, especially in areas where wind resources are abundant and conventional fuel costs are prohibitive.

Conventional electrification options (those most often employed) include the extension of electric distribution grid systems and deployment of isolated thermal power plants combusting either diesel fuel or natural gas. Grid extension represents the preferred option for a majority of rural electrification programs. This is due to its lower bulk power costs, higher reliability, and ease of operation. In addition, rural electric service providers are relieved of the necessity of managing small power plants, which often introduce multiple

Grid extension represents the preferred option for a majority of rural electrification programs. This is due to its lower bulk power costs, higher reliability, and ease of operation.

paths to failure. Rural electric cooperatives and companies that have to handle both the generation and distribution of electric energy typically encounter more problems in the management of power generation, as compared to having to manage their electricity distribution. Generation systems can be complex and expensive and require a great deal of supervision and maintenance. In contrast, well-designed distribution systems are durable, do not require as much maintenance, and are relatively simpler to operate compared to generation plants. The cost of energy purchased from a transmission/distribution grid can be less than US$0.05/kWh. In contrast, energy produced from a thermal, biomass, or mini-hydroelectric plant can cost more than double that.

The factor that limits the use of extension-of-grid systems is commonly the demand of the rural electrification project in conjunction with the distance required to interconnect to the grid system.

The factor that limits the use of extension-of-grid systems is commonly the demand of the rural electrification project in conjunction with the distance required to interconnect to the grid system. Grid extension can cost in excess of US$30,000 per kilometer for medium-voltage systems. Therefore, the cost of line extension must be weighed along with the power requirements against the potential cost of remote power generation. In cases where the project location lies an unfeasible distance from an existing distribution grid, project proponents should evaluate the cost-effectiveness of isolated generation using a thermal plant (diesel or natural gas) or other hybrid isolated generation options, such as solar or wind power.

Power generation with remote isolated diesel generation can provide a viable alternative to grid extension; however, experience has shown that this option can also be problematic. Major issues arise due to inadequate preventive maintenance of the system. In addition, the low technical capacity of rural electric cooperatives and companies in the operation of motors and their components often causes project failures. Although diesel generators are very robust, mobilize them only when grid extension is not affordable and when sufficient technical capacity is on hand to assure effective operation and maintenance of a remote power generation system.

Any rural electrification power option has its associated costs, challenges, and benefits. To determine the optimal solution, consider:

- The level of energy demand
- The distance to the electric grid
- The service provider's level of technical capacity
- The natural resources in the project area

On a more macro scale, the analyst must take into account the energy required, the cost of alternatives, and more importantly, the future needs of the community. Energy generation and distribution systems are important drivers of current and future development within any community. Consequently, the selection of a power supply option is of vital importance to the current and future economic situation of that community.

Preliminary Electric Line Design

Preliminary line design of the electric distribution system requires:

- Developing a representative map of the proposed electric distribution system
- Estimating energy consumption and demand of the communities that will be served
- Dimensioning the substations, conductor, transformers, and other system devices

In recent years, preliminary design has employed GPS satellite receivers. These devices can record geographic coordinates of existing and proposed electric distribution lines and system devices. GPS use can assist analysts in determining the length of the primary voltage lines (also known as "primary") with an acceptable degree of accuracy, in both relatively flat and mountainous terrain. This methodology has accelerated the process of project evaluation. It also allows engineering staff to create reasonably accurate system maps. These maps are used to model and evaluate the distribution system, both technically and financially, without the need for detailed and costly field surveys. At the conclusion of this process, the project team is able to generate a geographical picture like that in Figure 2.

Preliminary design establishes the general layout of the distribution system and defines the system parameters. These parameters include line layout, conductor size, substation and line device characteristics, etc. The distribution lines will extend from the most likely point of interconnection with the existing transmission or distribution grid, to the houses, businesses, and small industries the new system will serve. If the new system employs isolated or distribution generation, the preliminary design includes the location of the generation system and the attributes of the new substation. Normally, distribution lines follow primary and secondary roads, or existing right-of-way, given that housing patterns also generally follow existing roadways. Constructing the electric distribution lines near roadways facilitates line maintenance. Maintaining lines that cannot be reached via an existing road is extremely problematic.

It is also important to geo-reference (i.e. define its existence in physical space in terms of a coordinate system) the location of the communities that form part of the project with a GPS receiver. This information comes into play in the demographic and engineering analyses to follow. In many cases, rural communities are grouped in a highly informal fashion, with a significant percentage of dispersed homes. Consequently, establishing the range and lengths of the proposed primary and secondary lines requires recording the locations of homes within the community. The analyst must also specify the geographic limits of the town centers (and the corresponding location of homes within it), as well as location of the more dispersed homes and/or farms. In addition, the location of important consumers (often referred to as productive uses of electricity consumers) such as factories, processing plants, mines, etc., should be recorded. These consumers may play key roles in the final design of the system, depending on their size and levels of energy consumption.

Preliminary design establishes the general layout of the distribution system and defines the system parameters.

Figure 2. The Tomoyo project location survey results, the path of the electric lines, and the communities benefited

DEMOGRAPHIC STUDY

The demographic study for an electrification project determines the number of project beneficiaries and the market characteristics. It also classifies the potential consumers as residential, commercial, or industrial. In addition, the demographic study evaluates consumer capacity and willingness to pay for electric service. The demographic study also compiles data pertinent to the demographic characteristics of the communities, the economic activities of the area, and the energy demand related to the productive utilization of electricity (such as workshops, micro-industries, or agro-industries). Collect these data using two types of surveys: one obtains global demographic data on the economic activities of the community, while the second collects and evaluates demographic data on the community members themselves. For a more detailed discussion of demographic studies, please see Module 6: *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*

The demographic study compiles data pertinent to the demographic characteristics of the communities, the economic activities of the area, and the energy demand related to the productive utilization of electricity

Community Survey

The community survey defines a profile of the attributes of the community. The results of this survey will include the location of the community, the number of inhabitants, type of household construction (mud, brick, etc.), the number of houses in the community, the types of economic activities and sources of income within the community, and the characteristics of education, health, and communication infrastructure within the community. Further details on the construction of a survey instrument can be found in Module 6.

The method often employed to collect data for this survey is to gather community leaders in a series of focus group meetings. This process allows the analyst to form a quick mental image of the community's characteristics, so as to help refine the community survey instrument. After refining the survey instrument, organize a survey team to conduct the survey. Using the data collected during the survey, conduct a visual inspection of the community to verify selected field data, including the types of economic activities prevalent in the area, the location of certain key businesses, and distances from key point within the community. Verifying data is an important exercise. Remember that project conclusions depend on the modeling and evaluation of the data collected.

Among other objectives, the community survey determines the number of homes within the community. The community survey also assists in estimating overall energy demand and consumption for the project area. Using this data, the analyst can determine the estimated number of potential users and categorize these future consumers as residential, commercial, or industrial. Data collected in this survey also assists in estimating the population growth rate of the community.

Energy Use and Willingness-to-Pay Survey

The energy use survey allows the analyst to estimate energy use as well as ability and willingness to pay for energy services by the surveyed community. The survey instruments employ sampling techniques to randomly identify and survey energy uses in homes, stores, and workshops found in the community. In addition, the survey determines the consumers' ability and willingness to pay for electric service. "Willingness to pay" is defined as the maximum amount a consumer is willing to pay for electric service. Results of willingness-to-pay surveys are presented in graphical form to illustrate the distribution of values over the range of collected responses.

WtP demographic surveys collect data on energy use and costs with respect to the surveyed population. The survey includes all energy resources, such as the kerosene consumption in lamps, the consumption of batteries in flashlights, the use of photovoltaic solar systems, and multiple uses such as refrigeration, mechanical machinery, agricultural products processing, irrigation, and any others found in the project area.

Energy use and consumer WtP analysis is examined in further detail in Module 6: *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*

DETERMINING AND PROJECTING ENERGY DEMAND

Projecting energy demand is extremely important for all power sector projects. Demand projections must be based on the prospective electricity market, constituted by its residential areas, commercial centers, factories, hospitals, schools, and other general infrastructure, as well as for any future investments in those categories.

The projection of demand includes historical data to project the number of consumers and system growth, as well as the specific use of electricity per consumer. Other issues that require consideration include infrastructure and population growth, new business development, and new technologies that could stimulate a change in energy consumption.

Demand analysis proceeds by disaggregating consumer categories, then projecting growth for each individual segment. Analysts normally divide growth into growth of the consumer group (population growth) and growth in energy consumption for each market segment. In addition, figures should include estimates for energy losses and public lighting within the projection of demand.

In non-electrified areas, the most reliable way to determine the average level of electricity consumption per category, for residential consumers in particular, is a WtP survey as described in the previous section. Willingness-to-pay surveys provide an estimate of existing electric and non-electric energy use, the sum of which can be converted into equivalent electric consumption. Performing an energy use survey in neighboring electrified areas provides a reference point for estimating electric consumption, but the basis for projecting electric consumption should remain the willingness-to-pay survey.

Consumer Distribution

The consumption/demand analysis disaggregates potential consumers, segregated by category, to illustrate levels of energy consumption. Consumer categories are linked to the economic activity of the consumer.

Demand analysis proceeds by disaggregating consumer categories, then projecting growth for each individual segment.

Consumer classification for rural electrification projects is no different from consumer classification by traditional electric distribution companies. Consumers at residential properties are included in the residential consumer category. Any type of business (a "productive use" of electricity consumer) is classified as either a commercial or industrial consumer. The consumer's business type and level of electricity consumption and demand determine whether the consumer is a commercial or industrial consumer. Generally, a commercial consumer would be a shop, while an industrial consumer would be a paper mill or any type of factory manufacturing products. Some rural electric service providers prefer to classify their commercial and industrial consumers in two additional sub-categories, such as small commercial, large commercial, small industrial, and large industrial. The determinant for this level of sub-classification varies, although generally any energy demand less than 10 kW is considered small. In most cases, simply adopt the consumer categorization methods established by the electric distribution entity that serves (or will serve) the project.

With the above information now in hand, analysts making consumer projections must now consider two important electrification issues: the electricity penetration rate and the population growth rate.

Electrification Penetration Rate

The electrification penetration rate, also referred to as market penetration rate, consists of the percentage of consumers who are likely to connect to the electric service, over the total number of potential consumers within the population. This percentage varies from location to location. However, as an example, the average initial penetration rate in Bolivia varies from approximately 40% to 60% during the initial year of project implementation. During the subsequent years, more consumers usually connect to the electric distribution system. The penetration rate increases until it reaches a saturation point, occurring approximately six years after system energization.

Penetration rates can be expanded and accelerated through programs that reduce initial fees, or by allowing consumers to pay fees over a fixed period of time.

It takes more than one year for all potential consumers to connect to the system due to consumer preference and reluctance to change. However, for most potential consumers, the largest barrier to connection is cost. Penetration rates can be expanded and accelerated through programs that reduce initial fees, or by allowing consumers to pay fees over a fixed period of time.

To gain access to electric energy services, the consumer must normally pay both a connection fee and a fee for the installation of an electric meter. Gaining access to electric service also means the customer must be located close to a transformer or secondary power line. Service drop distances are generally limited to approximately 50 meters, but may be extended depending upon the policy of the rural utility. Customers located further away must generally pay an additional fee to cover the cost of the longer service installation, which may pose a significant impediment for the consumer.

Project planners must also take into account internal wiring installation and cost. Poor internal wiring can create safety hazards and can lead to damage of appliances and electrical machinery. While it is not typically the distribution utility's role to perform internal wiring installations, they should work with consumers and local electricians to ensure the installation of internal wiring to national or international standards.

An additional penetration rate roadblock is consumer perception. Often consumers believe the cost of electric service will be higher than it actually will be. This causes new customers or potential customers to wait and see what the new system can offer before they incur a new obligation.

A typical increase in the penetration rate after the first year is 3-5% per year for residential consumers. The analyst should design the growth model to ensure that penetration rates continue at this level until attaining the saturation point. The saturation point is defined from an analysis of the willingness-to-pay density function,[1] in comparison with likely electricity tariffs. The maximum penetration rate varies from region to region. However, in Bolivia, penetration rates have reached as high as 80 to 95% in several successful electrification projects. A significant influence on the penetration rate and the time it takes to reach the saturation point is the experience of adjacent communities that have already been electrified and have had experience dealing with the cost and benefits of a modern electric service.

The penetration rate for the other consumer categories, such as commercial and/or industrial consumers, may approach 100%. Most commercial and industrial consumers have a keen interest in reliable modern energy services to improve their production output and sales. Moreover, the cost of service provided by the project's electric grid is typically less than the cost of service of their current source of electricity. Therefore, these consumers readily subscribe to the electric service, if it proves to be reliable.

[1]A willingness-to-pay density function is a population of reported or measured responses indicating each surveyed consumer's willingness to pay for electric service from a specific energy service. Therefore, analysts will define a density function of WtP for lighting, another for refrigeration, another for television, etc. Generally, one measures WtP for lighting and "entertainment devices" collectively. The "density function" implies a collected population of responses, measured in percentage of the total surveyed population indicating WtP in US$ per month (or other currency) for the electric or energy service.

Using the results of the WtP survey, analysts generate a curve describing the willingness/ability to pay for energy services (in monetary value) as a function of the percentage of community members. This distribution very effectively predicts the initial and final penetration rates of the new electric service.

If the amount a consumer pays for traditional energy sources such as candles, kerosene, and small batteries is greater than the estimated cost of electric service, including the cost of converting to the service (house wiring, lamps, etc.), then consumers generally choose to connect to the electric service. Figure 3 illustrates the relationship between the number of people surveyed and their reported monthly energy expenditures for the Tomoyo project. The results demonstrate that 90% of the beneficiaries of the project have a willingness to pay the minimum tariff of Bs 20 (Bolivian Pesos) that the consumers of a similar electric service in the nearby town of Potolo currently pay. Note that if the monthly energy bill is as high as Bs 30, the percentage of likely consumers willing to pay drops to approximately 55%.

Consumer Growth Projection

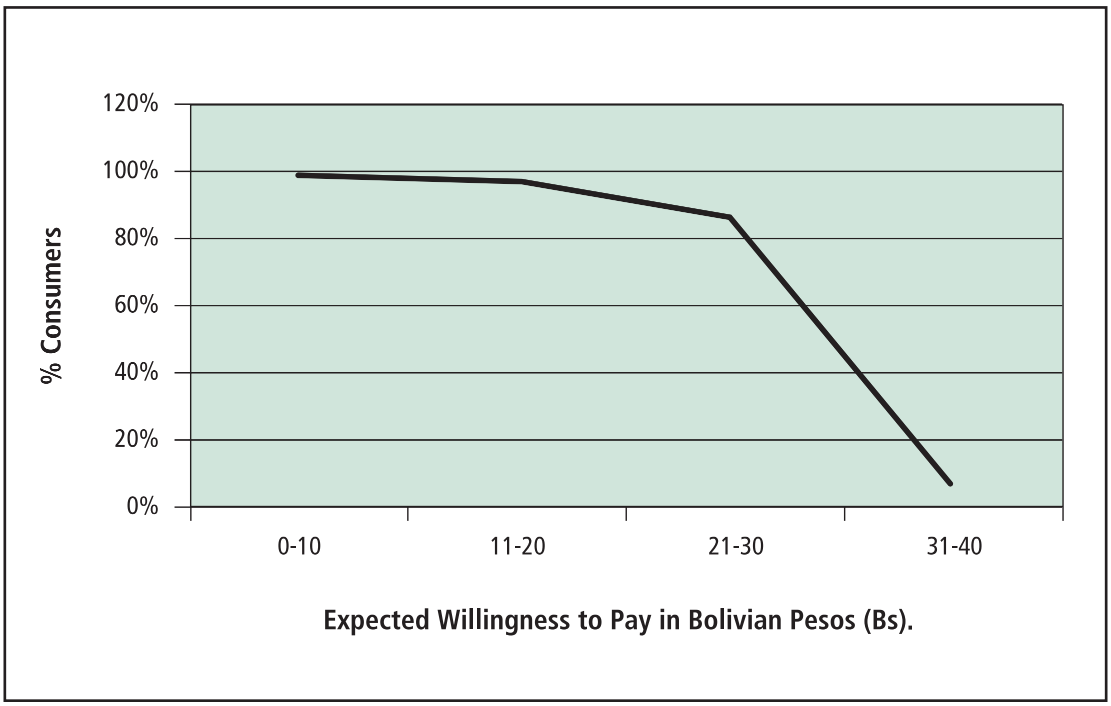
As shown in Figure 3, the Tomoyo project's willingness-to-pay study indicates that up to 85% of the population is willing to pay up to 25 Bs/month for electricity. However, to project future electricity consumption and demand, the analyst must classify the users into their respective consumer categories and project levels of electric consumption for each category. Using those data, the analyst constructs a growth projection for both the quantity of consumers (per category) and their respective electricity demand/consumption patterns.

The projection of future consumption/demand provides a key starting point for evaluating the cost and viability of electrification projects. It is a requirement for dimensioning the electric distribution grid, evaluating generation options, and estimating the operating costs and revenues the project will generate.

Two main factors influence electricity consumption and demand projections: annual

The projection of future consumption/demand provides a key starting point for evaluating the cost and viability of electrification projects. It is a requirement for dimensioning the electric distribution grid, evaluating generation options, and estimating the operating costs and revenues the project will generate.

Figure 3. Capacity and willingness to pay (Tomoyo)



consumer growth and growth of specific energy consumption (kWh consumed per consumer-year). Annual consumer growth varies according to the electrification penetration rate and the growth rate of the population itself. Population growth rates are most often available from local or central demographic agencies. For example, the Bolivian National Institute of Statistics (INE), which conducts a national census every ten years, provided the population growth data for the Tomoyo project.

Table 2 illustrates the estimated residential consumer growth projections for the Tomoyo project. The calculations used a 2% population growth rate, along with a 50% electrification penetration rate during the first year. This resulted in 95% of the potential consumers connecting to the system by the fifth year of service. In addition to increasing the served population by the penetration rate, the model must increase the number of consumers by the reported growth rate of households (population growth rate divided by average household size).

For the Tomoyo project, the number of potential residential beneficiaries (potential consumers) was estimated at 763. During the first year of project implementation, analysts projected that 383 residential consumers would connect to the service, with the total served population reaching 1,020 residential consumers over a 20-year time frame. Table 2 shows a projection of a combination of commercial and residential consumer growth over the 20-year project life.

Table 3 summarizes the projection of electricity consumption for the Tomoyo project's residential and commercial consumer categories.

Estimating Electricity Consumption of Productive-Use Consumers

For residential consumers estimate the expected monthly consumption of electricity by reviewing both the results of the willingness-to-pay study and the records of the closest rural electric service. However, when estimating the electricity consumption patterns of productive use consumers (commercial and industrial users),

Table 2. Growth projection for residential consumers (Tomoyo)

CONSUMER GROWTH PROJECTION											
Domestic Consumers Category											
Community	Potential Beneficiaries	Years									
		1	2	3	4	5	10	13	15	18	20
Molle Molle (Chuquisaca)	48	24	30	36	42	48	53	56	58	61	63
Molle Molle (Potosi)	124	62	77	92	108	124	138	147	153	162	168
Sorojchi	102	51	63	76	89	102	112	118	122	129	135
Yoroca	58	29	36	43	50	58	63	66	68	71	73
Tomoyo	78	39	49	59	69	79	89	95	99	105	109
Llajtapata	92	46	57	68	80	92	102	108	112	118	122
Isluco	49	25	31	37	43	49	54	57	59	62	64
Joroja	72	36	45	54	63	72	79	85	89	95	99
Sorocoto	97	49	61	73	85	98	108	114	118	124	129
Soroscopa	43	22	27	32	37	43	48	51	53	56	58
TOTAL BENEFICIARIES	**763**	**383**	**476**	**570**	**666**	**765**	**846**	**897**	**931**	**983**	**1020**

Table 3. Consumption growth projection (kWh) for residential and commercial users categories (Tomoyo)

CONSUMPTION GROWTH PROJECTION (kWh)											
Residential and Commercial Consumers Category											
Category	Potential Beneficiaries	Years									
		1	2	3	4	5	10	13	15	18	20
Domestic	763	457	533	610	689	770	852	903	937	990	1027
Commercial	42	42	42	47	48	50	65	77	84	96	107
TOTAL	**805**	**500**	**577**	**660**	**741**	**825**	**927**	**993**	**1036**	**1104**	**1154**

look at their product volume of production and the energy generally used by these consumer categories to determine their expected electricity consumption.

As an example, the Tomoyo project team established that residential consumers' average consumption was 25 kWh per month. However, the consumption estimates for commercial consumers varied more widely. Therefore, the project team classified the different commercial consumer types according to a market evaluation, determining average consumption patterns for each classification. Table 4 presents the results.

Electricity Consumption Growth Rate

The electricity consumption growth rate is a key variable for the estimation of energy demand. Energy consumption naturally increases over time as consumers grow more accustomed to electric energy use and as economic activities grow. This is commonly due to residents' acquisition of home electric appliances such as televisions, refrigerators, blenders, etc. Therefore, analysts must estimate an electricity consumption growth rate and apply it to the average yearly electricity consumption estimate for residential consumers.

Commercial and industrial consumers' electricity consumption patterns also grow, but usually at higher growth rates. Projections often utilize estimates of new business development and estimates of energy consumption similar to those shown in Table 4, based on the best sources of information available. Be careful not to overestimate electric consumption from surveys performed in the project area, as local officials and residents typically overestimate demand. To construct a conservative growth model, cross-check information, employ proper judgment, and apply reasonable growth rates to consumption models. Tables 5 and 6 summarize the calculations made for the projected kWh consumption growth for residential and commercial customers, per community, for the Tomoyo project.

Public Lighting

Public lighting is another key component in the projection of electricity demand. Some rural electrification projects include public lighting

Table 4. Estimate of electrical demand, per activity

Productive Use	Monthly Average Consumption kWh	Annual Average Consumption kWh
Stores	75	900
Mills	250	3,000
Health Clinics	150	1,800
Schools	100	1,200
Minor Productive Uses	120	1,440
Water Service	1,350	16,200

Energy consumption naturally increases over time as consumers grow more accustomed to electric energy use and as economic activities grow.

Table 5. Electricity consumption growth projection – residential consumers (Tomoyo)

ENERGY PROJECTION – Kwh											
Residential Consumers											
Community	Potential Beneficiaries	Years									
		1	2	3	4	5	10	13	15	18	20
Molle Molle (Chuquisaca)	48	7,200	9,180	11,236	13,371	15,587	19,002	21,306	22,959	23,209	24,938
Molle Molle (Potosi)	124	18,600	23,562	28,715	34,383	40,266	49,477	55,929	60,564	61,637	66,502
Sorojchi	102	15,300	19,278	23,721	28,334	33,122	40,155	44,896	48,293	49,081	53,439
Yoroca	58	8,700	11,016	13,421	15,918	18,834	22,587	25,111	26,917	27,014	28,897
Tomoyo	78	11,700	14,994	18,415	21,967	25,654	31,909	36,145	39,189	39,950	43,147
Llajtapata	92	13,800	17,442	21,224	25,469	29,875	36,570	41,091	44,334	44,896	48,293
Isluco	49	7,500	9,486	11,548	13,690	15,912	19,360	21,687	23,355	23,589	25,334
Joroja	72	10,800	13,770	16,854	20,057	23,381	28,324	32,340	35,230	36,145	39,189
Sorocoto	97	14,700	18,666	22,785	27,061	31,824	38,721	43,374	46,710	47,179	51,064
Soroscopa	43	6,600	8,262	9,988	11,779	13,963	17,209	19,404	20,980	21,306	22,959
TOTAL BENEFICIARIES	**763**	**114,900**	**145,656**	**177,908**	**212,029**	**248,418**	**303,314**	**341,284**	**368,530**	**374,005**	**403,761**

Table 6. Energy consumption growth projection – commercial consumers (Tomoyo)

ENERGY PROJECTION – kWh											
Commercial Consumers											
Communities	Potential Beneficiaries	Years									
		1	2	3	4	5	10	13	15	18	20
Molle Molle (Chuquisaca)	4	6,800	6,936	7,075	9,020	9,201	12,190	15,092	17,945	21,424	24,766
Molle Molle (Potosi)	6	9,154	9,337	11,111	11,334	11,560	16,410	21,285	24,158	29,909	33,340
Sorojchi	5	6,240	6,365	7,791	7,946	8,105	11,932	14,245	16,467	19,223	23,635
Yoroca	5	6,900	7,038	8,615	8,787	8,963	13,194	15,752	18,209	21,256	26,135
Tomoyo	8	13,632	13,905	15,956	16,275	18,445	24,437	30,255	35,974	42,948	49,648
Llajtapata	2	2,700	2,754	2,809	2,865	2,923	4,840	6,849	7,125	9,452	9,833
Isluco	2	2,100	2,142	2,185	2,229	2,273	3,765	5,327	5,542	7,351	7,648
Joroja	2	2,100	2,142	2,185	2,229	2,273	3,765	5,327	5,542	7,351	7,648
Sorocoto	7	8,400	8,568	9,988	10,188	11,690	15,775	19,785	22,167	26,885	31,467
Soroscopa	1	1,050	1,071	1,092	1,114	1,137	2,510	2,663	2,771	2,941	4,589
TOTAL BENEFICIARIES	**42**	**59,076**	**60,258**	**68,806**	**71,986**	**76,569**	**108,817**	**136,578**	**155,900**	**188,739**	**218,711**

as an important economic benefit the project can offer within the project area. Public lighting is often employed in areas of higher population density, such as in towns and cities.

Estimate energy consumption and demand for public lighting by using a lighting standard adopted by the distribution cooperative or utility, if a standard has been established. The majority of rural electric service providers have established an approximate relationship between total demand and public lighting, wherein public lighting represents 7% of residential consumers' total demand. Other service providers determine an approximate consumption value for public lighting using a "per number of consumers" calculation. For example, a service provider might install a 70 W sodium vapor lamp or a 125 W mercury vapor lamp for every 6 to 10 homes within a densely populated community. For most projects, we recommend estimating the number of public lamps to be installed, then determining the lamp size, and finally calculating the energy consumption for public lighting from those two items of information.

Be sure to establish a viable payment mechanism for public lighting systems prior to making the final decision to include them as part of the electrification project. The energy cost associated with public lighting can be significant. It can transform a project from being financially viable to non-viable. Project planners must make certain that public lighting bills are accepted and paid for, either by the local or national government, or as a line item on the consumer's bill.

Distribution System Losses

Distribution system losses are important in estimating total energy and power needs. Project planners must consider distribution system losses in two categories, technical and non-technical losses. Technical losses are losses of electrical energy attributed to the impedance of the conductor, the level of current passing through the conductor, and so-called transformer core losses. Non-technical losses include theft and various types of inefficient or ineffective management, such as unregistered consumers, damaged meters, and poor meter reading practices. Electricity losses constitute an important factor for a project's financial feasibility.

Assume that the project interconnects to an existing electric transmission or distribution grid. In this case, the most practical way to register the amount of system losses consists in applying, to the demand projection, the same loss percentage used by the respective electric utility. Acceptable technical losses for distribution service providers vary in the range of 7-12%. Non-technical losses are controllable and should be kept near zero with diligent management. Higher losses affect the project's feasibility. Technical losses are relatively easy to calculate using a load-flow engineering program. Remember to calculate the losses only after considering all of the project's energy demand factors.

Non-technical losses are controllable and should be kept near zero with diligent management.

Consumption and Electricity Demand Projection

The demand projection for the project area takes into account expected electricity consumption as well as expected growth in electric power demand. Calculate the growth in electricity consumption using the change in electricity consumption for each category of registered consumers, in kWh, as was explained above. The demand is the amount of power that the project area's loads demand, and that the distribution company must produce or purchase, to ensure that all consumers have adequate power available when required. Demand is measured in kW or MW.

Breaking the demand projection process into steps, begin by constructing a consumer growth projection over the project life. To this, add the growth of specific consumption (energy consumption per consumer), also over the project horizon period for each consumer category. Next, multiply the number of consumers (for each category) by specific consumption (also for each category) to calculate total consumption for each consumer category. Finally, add the consumer category annual consumption for each project year. Table 7 summarizes the projection of electricity consumption for the Tomoyo project.

Next, we calculate the demand (in kW). The estimate of demand not only defines the technical characteristics of the power lines, but also aids project planners in anticipating sufficient energy supply and generation. Project planners also use demand estimates to design the substation and determine the number of feeders and their location and orientation. The methodology used to calculate power demand for predominantly residential consumers is detailed in the Rural Utility Services (a division of the USDA) REA 45-2 Bulletin (USDA - RUS).[2] Even though this methodology is based on empirical data from the United States, it has been used successfully in Latin America and in other regions, and thus, it is appropriately used to determine demand for rural electrification projects.

[2]"USDA Rural Development's Electric Programs - Bulletins." United States Department of Agriculture - Home. 26 Feb. 2009 http://www.usda.gov/rus/electric/bulletins.htm.

Calculating of power demand according to the method described in the REA Bulletin 45-2 requires the number of consumers and the monthly average consumption in kWh per consumer. The method defines the Consumer Factor (Factor "A") and the Electricity Consumption Factor – kWh - (Factor "B"), where Factor "A" reflects the increased diversity that results from the increase in the number of consumers, and Factor "B" reflects the increased load factor that results from an increase in energy use. See Equation 1 for the precise formula.

Equation 1. Recommended formula for calculating power demand

D = (Factor A) * (Factor B)

Factor A = C*(1-0.4*C+0.4*(C^2+40)^0.5)

Factor B = 0.005925*(kWh/month/consumer)^0.885

Where:

D = Demand (kW)

C = number of consumers

Tables 8 and 9 demonstrate the power demand projections for the Tomoyo project. Table 8 illustrates the demand projection for the residential consumers in each community involved in the

Table 7. Projected electricity consumption – kWh (Tomoyo)

Concept		Total Electricity Consumption – kWh									
		Years									
		1	2	3	4	5	10	13	15	18	20
Total Domestic Consumption of Electricity kWh		114,900	145,656	177,908	212,029	248,418	303,314	341,284	368,530	374,005	403,761
Total Commercial Consumption of Electricity kWh		59,076	60,258	68,806	71,986	76,569	108,817	136,578	155,900	188,739	218,711
Public Lighting kWh	7%	8,043	10,196	12,454	14,842	17,389	21,232	23,890	25,797	26,180	28,263
Losses kWh	15%	32,121	38,137	45,735	52,740	60,419	76,476	88,544	97,099	103,928	114,835
Total Consumption in kWh		**214,140**	**254,247**	**304,903**	**351,597**	**402,796**	**509,840**	**590,296**	**647,326**	**692,851**	**765,570**

Table 8. Residential demand projection per community in kW (Tomoyo)

PROJECTION OF THE DEMAND IN – kW										
Residential Consumers										
Community	Potential Beneficiaries	Years								
		1	2	3	4	5	10	13	15	20
Molle Molle (Chuquisaca)	48	3	4	5	5	6	7	8	9	9
Molle Molle (Potosi)	124	7	9	11	13	14	17	20	21	23
Sorojchi	102	6	7	9	10	12	14	16	17	19
Yoroca	58	4	5	5	6	7	9	9	10	11
Tomoyo	78	5	6	7	8	10	12	13	14	15
Llajtapata	92	6	7	8	9	11	13	15	16	17
Isluco	49	3	4	5	5	6	7	8	9	9
Joroja	72	4	6	7	8	9	10	12	13	14
Sorocoto	97	6	7	9	10	12	14	15	16	18
Soroscopa	43	3	4	4	5	6	7	7	8	9
TOTAL BENEFICIARIES	**763**	**40**	**51**	**62**	**73**	**85**	**103**	**115**	**123**	**135**

Table 9. Total demand projection in kW (Tomoyo)

TOTAL PROJECTION OF THE DEMAND – kW												
Residential – Commercial – Public Lighting – Losses												
	Concept	Potential Beneficiaries	Years									
			1	2	3	4	5	10	13	15	18	20
1	Residential Consumers - kW	383	40	51	62	73	85	103	115	123	126	135
2	Commercial Consumers - kW	42	20	20	23	24	25	34	42	47	56	64
4	Public Lighting - kW		4	5	6	7	8	10	11	12	12	13
5	Losses - kW		10	12	14	16	18	23	26	29	31	34
Total Coincidental Demand kW			**70**	**83**	**99**	**115**	**131**	**163**	**187**	**204**	**218**	**239**

project. Table 9 presents the demand projection for all consumer categories served by the project, including the demand for public lighting, and expected losses. The analyst must remember that the demand calculation resulting from the electricity consumption data does not include losses. Calculate losses separately, and include them as an itemized component of the overall demand projection.

ENGINEERING ANALYSIS AND COSTS ESTIMATE

The next phase of the project feasibility study focuses on the engineering analysis of the electric system design. In this phase, analysts dimension and configure the electric distribution system, then estimate the overall capital cost of the project. In this part of the feasibility analysis, the project team decides several characteristics of the electrical lines, including:

- Voltage level
- Whether the project will provide single or three phase service
- Conductor size
- Line devices, voltage regulation, capacitor banks, and other system characteristics required to control power quality

The electric system has to provide its consumers with reliable service that complies with the appropriate quality standards.

With all this information resolved, the analyst can finally estimate the construction costs of the project.

The previous planning phases determined the geographic location of the project, including the path and length of the power lines. The demographic and willingness-to-pay analysis of the project yielded the number of beneficiaries as well as the energy demand for the project. Using these data, the analyst can evaluate alternative configurations for the substation, distribution lines, and components of the electric system to ensure quality and reliability within the system.

This section describes the engineering analysis methodology used to determine the electrical parameters of the distribution lines and the process used for evaluating the project's design options. The energy demand, losses, voltage drop, and economic evaluations are all factors to account for when determining the number of phases, voltage level, and size of the conductors selected for the project. Project planners must consider and evaluate the construction costs, not only to ensure a reliable feasibility study, but also to enable selection of the lowest cost construction option, and therefore the lowest investment cost, possible for the project.

Factors That Affect System Design

Electric systems utilize materials such as poles, transformers, conductors, etc. that typically have a useful life of approximately 25 to 30 years. Therefore, analysts must base the project's depreciation schedule on accurate useful-life information.

Moreover, the electric system has to provide its consumers with reliable service that complies with the appropriate quality standards. In addition, the system must supply the required voltage for the correct operation of electric machines and devices that may run on the system. To achieve this goal, the electric system design must incorporate solid electric distribution industry standards and practices. Above all, the goal of the engineering design analysis must ensure that the system incorporates the main principles of rural electric systems, namely:

- Establish and maintain voltage levels within a range of +/- 7%.
- Use the correct caliber of conductor, which maintains voltage levels and loss level targets over the intended project horizon.
- Employ design standards to assure that safety standards (clearances and insulation levels) are established and maintained.
- Employ a well-defined design and construction standard, to assure cost control and quality of service over the project life.

The engineering and system design analysis starts by projecting the consumption and demand on the system. The demand analysis supplies the maximum consumption and demand on the system. Analysts then multiply the maximum demand estimate by a safety factor, usually 1.5, to prevent catastrophic failures in electrical and mechanical design of the distribution system.

The second step consists of determining the electric system's voltage level. Most rural electric systems have fewer consumers per kilometer than urban distribution systems do. In addition, rural systems have a greater total length of line. Therefore, the normal practice is to use higher voltage levels for the primary distribution system, such as 25-35 kV. In many cases the voltage level is already established and standardized by the national government, the largest electric company of the country, or by the existing infrastructure in the project area.

The selection of the size (diameter) and type of conductor used must also take into account a few practical factors. For example, the process of changing conductors in rural electrical lines is very expensive. Therefore, the design commonly uses a conductor that meets the required load for the duration established for the project, normally 20 to 30 years. In the case of the Tomoyo project, this was for a 20-year useful-life, according to the demand projection.

Furthermore, the design of a rural electric system has to consider these factors in the context of minimizing construction costs. Due to the various factors involved in the design of the system, the process of minimizing these costs is calculated by utilizing iterative and interrelated steps when modeling the system. For instance, analysts calculate the voltage drop values, calculating the size/caliber of conductor needed, and/or calculating the voltage level at which operational parameters fall within pre-determined acceptable ranges.

Residential consumers in rural areas often request three-phase distribution lines, even when building the system with single-phase lines is more cost effective. Note that single-phase distribution lines are adequate for carrying up to 25 amps of load in the primary distribution system. A system requires three-phase lines to transport loads of more than 25 amps and provide adequate protection against overcharges. Lines with individual currents or motors greater than 10 hp are also better served by three-phase lines. However, a new technology called virtual pole motors is now able to serve larger loads, up to 100 hp, with single-phase service only.

The cost advantages of employing single-phase construction are so great that project planners should seriously consider single-phase construction for all rural electrification projects. Single-phase construction can save up to 50% of overall construction cost and can represent the difference between a feasible and a non-feasible project. Moreover, a single-phase system can be converted to three-phase construction if required in the future. Both recent World Bank standards and historic REA of the U.S. design standards propose the overarching objective of minimizing construction costs to achieve higher levels of access, while maintaining adequate safety and quality of service standards for rural areas. Generally, projects should employ single-phase construction as the default option, while assuring maximization of the ruling span to up to 120 meters, where possible. Further, minimization of the secondary (low voltage) distribution system is strongly recommended to maintain low loss levels. In addition, project planners can couple the secondary distribution system with the use of small, single-phase transformers, with services extending no more than 50 meters in length, to further reduce loss levels and cost.

The cost advantages of employing single-phase construction are so great that project planners should seriously consider single-phase construction for all rural electrification projects.

Analysts can further reduce the total cost of the primary distribution lines, in areas of very low population density and subsequently very low loads, by using single wire, earth return construction. The REA never sanctioned this design. Concerns with so-called "stray voltage" that can result in reduced milking volumes in mechanized dairies, along with concerns over possible interference between ground return lines and older commonly non-insulated telephone circuits prevented its approval.

While this design was never employed in the United States, it was developed in Australia in the 1960s, and used there extensively, as well as later in Chile, Mexico, Tunisia, and other countries. The security issues have been resolved, and interference with the non-insulated telephone lines has become less of a concern, due to changes and advances in telecommunications technology. Consequently, several government and self-financed electrification programs in Latin America, Asia, and Africa have begun to adopt single wire earth return designs in areas of low energy demand.

The application of a single wire, earth return design is feasible when the demand on the lines will not grow greater than eight amps and where theft of the neutral conductor is common. When compared to a multi-grounded neutral single-phase system, the savings in overall system cost materialize in the use of shorter poles. The shorter poles can be used because of the elimination of the neutral cable in this system's design.

Selection of an appropriate engineering package is important, as some products lack the necessary functions and characteristics

Controlling Technical Losses

Controlling technical and non-technical losses is extremely important for project feasibility from the financial point of view. Keep in mind, however, that not all system loss reduction techniques come into play during the design phase of the feasibility study. For example, the primary way to evaluate a transformer's losses is by analyzing the financial value of its losses, whether those are voltage or current losses. This procedure occurs during the purchasing phase of the project, not during the system's design. For more on this issue, see Module 7: *Distribution Line Design and Cost Estimation for Rural Electrification Projects.*

Voltage Drop/Load Flow Analysis

Once the power line parameters are defined, including the voltage level, number of phases, and conductor size, modeling of the distribution system begins. This process utilizes engineering software to analyze voltage drop and load behavior over the life of the project.

Selection of an appropriate engineering package is important, as some products lack the necessary functions and characteristics. At a minimum, the program selected for modeling of the distribution system should have the following capabilities and characteristics:

- Employ constant load as opposed to the constant current method
- Be able to calculate imbalanced loads and analyze single-phase lines
- Be able to calculate the effects of reactive energy in overhead lines

Most modern load flow programs include an interface that allows a seamless transfer of geographically referenced data when uploading georeferenced distribution line data into the engineering model. To model the system or the power lines for the new project, the electrification lines can be drawn in the user's geographical interface (i.e. the GIS), permitting the introduction of field-collected GPS data. In many cases, depending on the software used, the system maintains the scale of the georeferenced data and therefore maintains the appropriate lengths of the electric lines and distances between communities.

In the majority of load flow programs, analysts must provide the following information to start modeling the power lines:

- Line voltage
- Number of phases
- Conductor size
- Conductor impedance
- Length of conductor
- Demand at each load point of the electric grid
- Capacity (in kVA) of the substation transformer(s)
- Characteristics of the distribution transformers (capacity, primary/secondary voltage, impedance, available taps, connection configuration, regulation, sequence, and protection configuration)

Feeder analysis starts at the output section of the substation, ending at each line terminal, including its deviations. The analyst can perform load flow analysis for distinct project phases, such as at the five-year, 10-year, and 20-year marks, using load projections for each phase. However, the analysis must draw from the project's final year demand projection study to define the characteristics of the project's three-phase feeders. This means the analyst should carry out an analysis of the system for year zero and then for the last year of the project's evaluation timeline.

If the analysis shows unacceptable levels of voltage drop and/or losses, changes in system design are required. From here, the project team has a choice of several interventions. For example, one may choose to install voltage regulation equipment such as capacitor banks or voltage regulators to correct high voltage drop levels. Perform this analysis for varying load conditions, in accordance with the project time horizon, to determine the year when voltage regulation will be required. To correct the problem, the team could also shift the system from single to three-phase service, or increase the conductor size. Analysts must consider various alternatives, and evaluate the associated costs, to reconfigure the project to adequately meet load projections.

This process eventually results in defining the final recommended system characteristics, including voltage levels, single versus three-phase service, size of the conductor, and the use of other system devices. By using load flow programs to model the power lines and system, analysts can obtain information concerning the performance of the electric lines, according to the project's estimated demand. In addition, the programs enable the user to calculate the time frame requirements for additional investment.

Generally, load flow programs present the results of the electric system analysis both graphically and as a text report. The parameters presented normally include the voltage drop level, electrical loads, the demand in kW, the reactive power (kVAR), the power factor, and the energy losses in kW. Modelers can also calculate other system characteristics, and display them according to their preferences and interests. Figure 4 presents the Tomoyo project's engineering analysis, calculated using the listed assumptions and the previously described consumption/demand analysis.

Estimating Project Costs

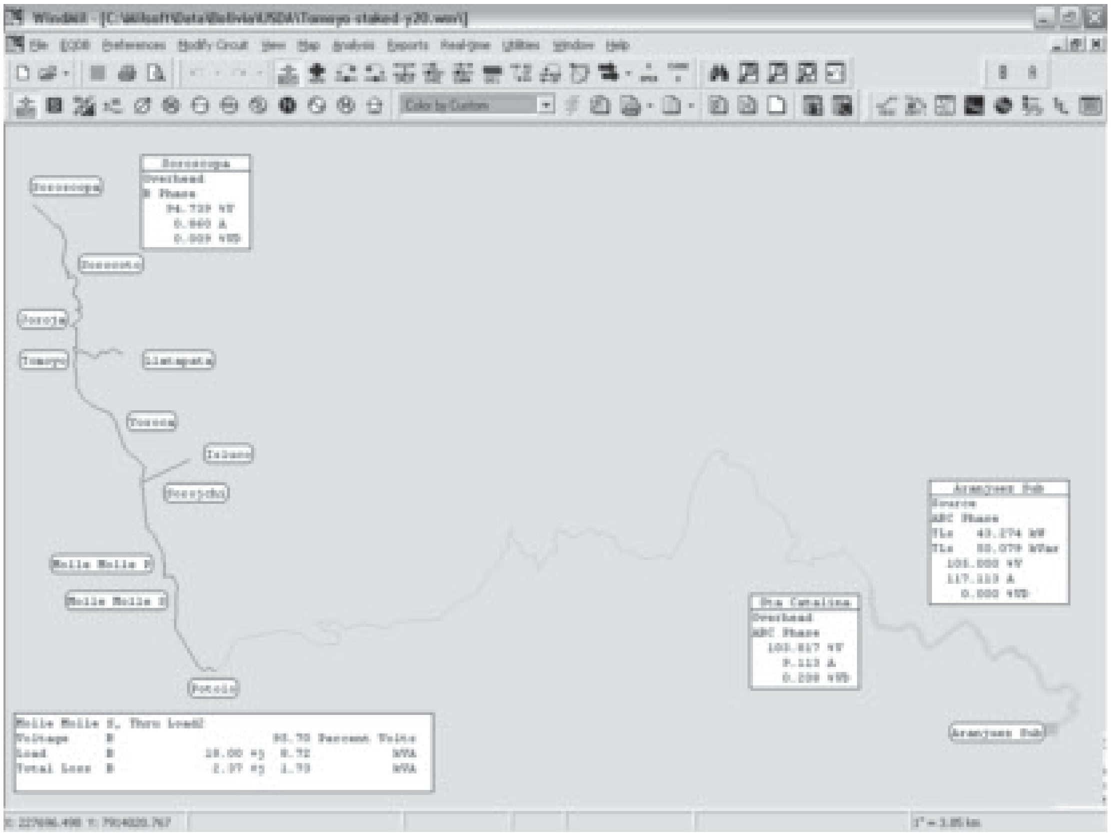
A central concern of all government agencies and international donors is how to minimize project cost, while meeting service quality and safety standards. If a project disregards service quality and safety standards, this causes an increase in future operating costs for the electric distribution service provider and its consumers. Project planners must find a balance between the economics of construction on the one hand, and sustainability considerations regarding operating costs and quality of service on the other.

If the analysis shows unacceptable levels of voltage drop and/or losses, changes in system design are required.

Construction costs relate directly to the standards employed during system design. Construction standards allow for the optimization of construction costs. Standards also aid in facilitating system reliability, service quality, and assuring reasonable service life of the infrastructure. Standards often include material specifications and detail inspection/acceptance procedures during the material reception process. The manufacturers who comply with construction standards are generally widely known within the industry, as are those who fail to do so.

Many national rural electrification programs have not yet adopted design and construction standards specifically for rural electric systems. For this reason, standards developed in the United States and Europe have been adopted and/or adapted by countries with significant electrification programs. The REA – now the RUS – offers vast experience with design and construction standards. In addition, REA standards include provisions for both single and three-phase service. Therefore, it may be preferable to use the REA standards as

Figure 4. Load flow study, Tomoyo project – year 20



a starting point when developing standards for a new rural electrification program.

Materials, Constructive Units, and Labor Database

To determine project cost, it is necessary to create a database of the construction costs for the primary and secondary voltage lines. This database should include data on the cost of materials, from which analysts can calculate costs per construction unit. Base a project's materials database on historic costs of projects already executed, as well as current quotes for similar materials. Combining these resources helps determine the cost of the primary and low-voltage lines. Enable the database to store unit prices, as well as the required quantities of each unit, per item. The unit prices can vary according to the quantity purchased. Generally, the larger the quantity purchased, the lower the price. The materials must be selected according to the voltage level (15, 25, 35kV) for the primary lines, as well as for the secondary lines (110V, 220V, 380V, 440V), since several items differ by voltage level.

The database should also store a unit cost variable for construction units of each kind of project material. Additionally, the database should include the cost of labor, based either on previous construction projects or on current quotes. Although project designers often employ previously complied material database quantities and costs, it is important to update the unit prices to account for price increases since the database was originally developed.

Projects are composed of line segments that serve specific geographic service areas. These line segments are in turn composed of "structures" – standard configurations of utility poles, cross-arms, and line hardware assembled to assure structural integrity. REA standards, as adapted by NRECA for use in Latin America, specify standard construction units (structures) for each standard voltage level.

The use of REA standard construction units allows engineers to define the number of distinct structures, then tabulate and group each structure with its corresponding set of hardware components, cross arm characteristics, and pole type. By developing a matrix of the structures and their components, together with unit costs for each component item, analysts can calculate the total line segment and project cost.

Module 7 contains an example of a database for a common construction unit: the ZA1. The database combines the description of the component, quantity of components per construction unit, unit cost of the component, total cost of the component, and the total cost of the construction unit.

The costs database for an electric distribution grid must include all proposed construction units for building not only the primary and secondary lines, but also the transformer banks. To add a further level of sophistication, add a "type of terrain" column to the database to create a distinction between line construction on level or rugged terrain. This way, project planners can adjust unit costs for different segments of the project and model final cost estimates with more precision. In addition, this creates a tool for the field analyst to apply an appropriate cost per unit based upon that unit's surroundings and location.

It is quite useful to establish an historical cost database, containing data on material costs, construction units, and staking costs, as a reference for future projects. Naturally, one must update this database before using it in subsequent projects. However, by storing historical cost data for each endeavor, the analyst will find that updating stored cost data takes less time and effort than starting anew.

A database for construction units per kilometer of feeder can be found in Module 7.

In contrast to calculating the primary line costs, determine the cost of secondary lines by calculating the average length of secondary line per user, sometimes including a connection cost. Then present the costs in the form of an average cost per connected user. The procedure to determine the cost of low-voltage lines is the same as the one described above for primary lines.

Staking Costs Database

Analysts must estimate the cost associated with distribution line design as an integral part of the project budget. The costs database must include the staking cost per kilometer of primary line or per feeder and the staking cost per user for the low-voltage distribution grid. See Module 7 for more information.

At this point, all necessary cost data have been gathered and calculated, and the analyst can now estimate the total project cost. Table 10 demonstrates an example of an estimate for a project's total costs.

ECONOMIC ANALYSIS OF THE PROJECT

The many and multiplicative benefits of a project are sometimes difficult to quantify in real terms. Yet economic development requires the implementation sustainable electrification projects.[3] Therefore, it is important to perform an economic benefit analysis, evaluating several well-defined categorized benefits including, educational benefits, health benefits, entertainment and communication value added, quality of life improvements, security benefits, and increases in productivity. While the economic value of each categorized benefit can be estimated, the methodology to estimate these values varies with the category of the benefit. A detailed explanation of the methodology for estimating the economic

[3]Douglas Barnes, *The Challenge of Rural Electrification: Strategies for Developing Countries.* (Washington, D.C.: Resources for the Future, 2007).

Table 10. Sample total cost estimate (Tomoyo)

Community	km	Potential Users	kW	kWh	Staking	Cost Primary Lines	Cost Secondary Grid/ Connection	Cost of Supervision	Total Cost	$/Us
Molle Molle (Sucre)	4.2	52	7	1,560	$5,731.6	$16,352.7	$20,012.7	$1,262.9	$43,359.9	$833.8
Molle Molle (Potosi)	1.4	130	17	3,900	$11,158.8	$5,557.5	$50,031.8	$2,002.4	$68,750.5	$528.9
Sorojchi	2.2	107	14	3,210	$9,527.6	$8,396.7	$41,180.0	$1,773.1	$60,877.4	$569.0
Yoroca	2	63	9	1,890	$5,855.5	$7,683.0	$24,246.2	$1,133.5	$38,918.22	$617.8
Tomoyo	4.1	86	11	2,580	$8,482.5	$15,939.3	$33,098.0	$1,725.6	$59,245.3	$688.9
Llatapata	2.5	94	12	2,820	$8,595.6	$9,890.4	$36,176.8	$1,639.9	$56,302.7	$599.0
Isluco	2.1	51	7	1,530	$4,932.8	$8,365.5	$19,627.9	$987.8	$33,913.9	$665.0
Joroja	1.6	74	10	2,220	$6,627.7	$6,236.1	$28,479.6	$1,240.3	$42,583.7	$575.5
Sorocoto	3.2	104	13	3,120	$9,661.7	$12,632.1	$40,025.4	$1,869.6	$64,188.8	$617.2
Soroscopa	2.4	44	6	1,320	$4,464.1	$9,539.4	$16,933.8	$928.1	$31,865.5	$724.2
	25.8	**805**	**106**	**24,150**	**$75,038.0**	**$100,593.0**	**$309,812.0**	**$14,563.0**	**$500,006.0**	**$621.0**

Analysts measure financial viability by evaluating one of several investment recovery indicators, such as return on equity (ROE), internal rate of return (IRR), or the net present value (NPV) of project net revenues.

benefits of electrification projects can be found in Module 6: *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*

FINANCIAL ANALYSIS

This section describes the financial analysis methodology used for rural electrification projects. Financial analysis is the process of evaluating the revenues and costs associated with offering electric service. It evaluates overall project viability from the point of view of the investment value of the project. Whereas economic analysis, described in the previous section, evaluates the non-monetary benefits to the community, financial analysis measures the financial costs and benefits to the investor and/or to the project itself. Financial analysis considers the investment cost of the electric system infrastructure, as well as the operating cost of the project and the revenues derived from tariffs on electric sales.

Using financial analysis, the project team can evaluate the stream of revenues and costs over the life of the rural electrification project. Revenues consist of consumer payments made to the electric service provider for the electric connection, as well as for the purchase and consumption of energy. Project costs include payments for long-term debt, the cost of purchased power, and management/labor expenses associated with operating and administering utility operations.

Financial analysis normally proceeds by developing and employing a financial model, commonly via a spreadsheet. The time horizon used to model rural electrification projects is usually 20 years, roughly equivalent to the expected life of the electric distribution system. This aspect of time is important since rural electrification projects take several years to reach maturity, when consumer connections have reached the saturation point.

The objective of financial analysis is evaluating project viability, measured against investor expectations. Analysts measure financial viability by evaluating one of several investment recovery indicators, such as return on equity (ROE), internal rate of return (IRR), or the net present value (NPV) of project net revenues. The investment institution that may finance the project then evaluates these indicators against their required “hurdle rates.” If the project financial performance equals or is greater than the hurdle rate, investors consider the project viable. If the investment indicator does not meet the hurdle rate, investors consider the project non-viable. However, assistance for non-viable investments may be available through capital subsidies.

Most rural electrification projects require some level of subsidy to reach viability. Subsidies are assigned against investment costs (not to cover operating costs). Development experts usually consider subsidies justifiable when the economic benefits of a project is greater than the subsidy requested

Financial Analysis Data Requirements

The information required to perform a financial analysis includes investment costs, market data, and operational costs. This section explains and provides comments on each source of information.

Investment Costs

The investment costs include all costs required to build and finance the electric system during construction. These costs include the purchase of land and other infrastructure (such as offices, substations, right of ways or easement access); the design cost of the electric system; the cost of materials, such as poles, conductors, transformers, etc.; labor costs for construction; and the cost of the electric generation plant and transmission system, if applicable. These costs should also include a contingency allowance; costs related to vehicles and tools; an estimate for the amount working capital required; and other initial costs associated with electric system start-up.

Market Data

To perform project financial analysis, the analyst requires the market data collected and analyzed during the demand analysis. The market data consist of the projection of consumer connections (by year of the project) and the energy consumption and demand growth, so the analyst can evaluate revenues and energy costs for each year of operation. Additional input requirements for the financial model include the number of customers for each consumer category, the population growth rate, the total number of customers, and the average monthly consumption for electricity by consumer category.

The cost of purchased power is usually in the range of 60-70% of the total operating cost of an electric utility. Evaluating the energy consumption by year, and the total cost associated with power purchased is therefore crucial. Similarly, the tariff paid by consumers to the rural electric service provider, and the amount of energy sold to them, represent the primary source of revenue for the rural electric service provider. If the rural electrification project requires distributed (or isolated) generation, then the model must also evaluate the cost of energy generated, including all costs (fuel, plant maintenance, spares, lubricants, labor, etc.) associated with the remote power station. The cost should also include the depreciation allowance and long-term debt service required to finance the remote power plant, in addition to other operating costs.

When the project envisions forming a new electric cooperative or utility, the development of a synthetic (conceptual) distribution utility can enable the estimation of the operational costs.

Operational Costs

The operational costs include the total costs related to the administration and operation of the electric system. These costs include the purchase of energy, customer service costs, fixed costs, operation and maintenance variable costs, administrative and general expenses, and the costs for other external services. In addition, other operational cost items include the estimated taxes, invoice collection efficiency, insurance, and other expenses.

When the project envisions forming a new electric cooperative or utility, the development of a synthetic (conceptual) distribution utility can enable the estimation of the operational costs. To evaluate synthetic utility costs, create a list of employee positions, estimating salary levels and employee benefit costs for each position, as well as other non-employee utility operating costs. Include other, non-employee operating costs in the calculation as well, such as computing costs (computers, printers, computer software, etc.); vehicular costs (vehicles and fuel); costs of maintenance materials; rent costs; and other plant costs.

The Financial Analysis Process

After compiling the information mentioned above, the next step is evaluating the financial data. Financial analysis classifies the costs and revenues, using consumer growth projections and electricity consumption and demand projections. Using these data, the model calculates annual net revenue streams. The model also evaluates the value of annual revenue streams by calculating investment indices, such as rate of return on equity, internal rate of return, and/or net present value of the life of project net revenues.

It is important to evaluate how changes in assumed conditions may affect project viability. The computerized financial model makes it possible to evaluate scenarios corresponding to alternative system designs, variations in consumption/demand projections, and variations in tariff and cost of purchased power structures. Sales projections depend on the population growth projections and economic projections for the area. Project feasibility analysis is an interactive process that evaluates the balance between sales levels and variations in costs.

Module 8: *Financial Analysis of Rural Electrification Projects*, presents a financial analysis model designed specifically to evaluate rural electrification projects. The following sections summarize some of the information presented in more detail in Module 8.

Statement of Earnings and Expenses

The balance sheet, which also evaluates earnings and expenses, presents several indicators related to the projected financial balance for each year of the project analysis period. First, the balance sheet summarizes projected revenues and total estimated expenses for each year of project operation. Net revenues (revenues less expenses) are expressed in several ways throughout the financial model to assist in evaluating profitability.

EBITDA, or earnings before interest, taxes, depreciation, and amortization, measures the ability of the utility to meet debt obligations, and for this reason, it is an important financial indicator. A service provider that cannot cover its operational expenses and debt service cannot maintain its operations without the aid of a subsidy, a perpetual support that very few companies can obtain.

EBIT, or earnings before interest or taxes, another important indicator, consists of revenues equivalent to EBITDA revenues, less amortization and depreciation of fixed assets of the project. Depreciation and amortization installments normally imply a contribution to a fund required to replace assets at the end of the useful life of the distribution system. Depreciation is an important expense that the company must cover to maintain long-term sustainability.

A third valuable indicator is earnings before taxes, which is equal to EBIT, minus the interest payments used to service debt. If the company does not generate sufficient earnings to cover its interest payments, then it will need a government subsidy or refinancing of the project's debt structure.

Finally, net earnings take into account all the project's expenses, including taxes.

Net Income Flow Analysis

The statement of net income flow represents the results of the projected revenues and expenditures, including collections, cost of operation, costs associated with the investment in infrastructure (payment of interest and capital), and taxes. As mentioned in the previous section, EBIT is the sum of all revenues and costs not associated with the payment of interest and taxes. Therefore, the net income flow analysis requires calculation of EBIT and evaluation of the interest and taxes, if they are applicable to the project.

This analysis applies the calculation to obtain net earnings for each year of the project implementation period. Since earnings and costs fluctuate with the purchase and sale of electricity and with the fluctuation of consumers over each project year, to the analyst must model the project for each year of the project implementation period.

Net earnings include all associated costs and take into account any subsidy applied to the project investment cost. This is the most important indicator for performing financial analysis on a given project. The net earnings figure shows the net amount available after all revenues and costs have been accounted for, including any subsidies that may be applied to long-term debt obligations.

Evaluating the Feasibility of the Project

Project analysts commonly evaluate financial feasibility by analyzing the project's annual net income. Annual net income indicates the project's financial performance for every accounting term of the project, applying all tariffs, operational costs, and the capital costs of the project. Analysts must evaluate net revenues provided for each project year using a discounting technique to evaluate the net present value of the investment. However, this requires that the discounted revenues be reduced using a discounting value. The value used to discount a net revenue stream is the weighted average cost of capital of the enterprise – the weighted average of the interest on long-term debt and the estimated rate of return on equity. Many investors set the investment hurdle rate at the weighted average cost of capital. Evaluating the average cost of capital leads to calculation of the net present value (NPV) of the annual net revenue stream. If the NPV is positive, then the project is feasible. If it is negative, then the project is not feasible.

Several factors can influence the results of the financial analysis, including the interest rate, electricity tariffs, and the project cost structure. The analyst must strive to employ realistic and defensible data within the financial projections. If analysis results indicate a non-viable project, then the elements contributing to non-viability should be evaluated in greater detail. However, analysts adjust project elements to improve project financial performance with great care and never without adequate justification.

The financial analysis process demands that the analysts identify the project risks. Any project has inherent risks, and the best way to mitigate those risks is by identifying and evaluating them as objectively as possible.

Financial analysis must consider the inherent uncertainty of the data. Adjusting inputs across a specified bandwidth allows for an evaluation of how a specified range of assumptions will affect project outcomes. The analyst can define and analyze a worst case (high costs, low sales) and a best case (low costs, high sales) to see the effects on viability. The best case and worst case define the extreme for project possibilities, and they surround the more probable scenario, known as the base case. This type of analysis, called bandwidth analysis, is a way of evaluating the weakness or robustness of the financial scenario that is presented within the business plan or to donor and funding entities.

Normally, the final financial scenario is primarily presented as the result of the financial analysis. However, it is useful to include a description of the minimum and maximum financial cases as well.

In addition to bandwidth analysis, consider also conducting a sensitivity analysis, which can aid in evaluating the risks related to project implementation. Most commonly, sensitivity

Annual net income indicates the project's financial performance for every accounting term of the project, applying all tariffs, operational costs, and the capital costs of the project.

analysis consists of holding all other factors constant while varying a single viable. The analyst then observes the resulting change in the project outcome. The results of the project are considered sensitive to a variable when its variation has a significant impact on project viability.

For example, the profitability of the project could be affected only slightly when the costs of operation and maintenance vary (logically, within the acceptable range of values), but it could change significantly when the interest rate varies for the total debt. This would mean that the feasibility of the project is sensitive to the interest rate. A further step would be to identify the highest interest rate that the project could sustain and maintain financial feasibility. For example, the analyst would increase the project interest rate until the earnings become equal to the expenditures, called breakeven point analysis. Breakeven analysis helps to establish the project's limits concerning certain key variables, such as in the example provided.

If unexpected or extreme results are observed when applying previous survey data to the financial model, then the analyst should evaluate these data and their assumptions.

Project Indicators

Financial and technical indicators characterize the financial and technical profile of electric distribution systems. Analysts use these indicators to compare performance against so-called best-practice benchmarks, defined by reviewing performance of well-performing electric utilities. Technical indicators, including energy consumption and power demand, provide an indication of the relative size of the utility and the environment in which it operates. Financial indicators measure the project or utility's financial viability with respect to standard investment performance measures.

The following two sub-sections describe standard electric utility system indicators and financial performance indicators for rural electrification investments. Since there are many other ways of characterizing investments and distribution system operational performance, these lists are not exhaustive. However, they illustrate how projects can be evaluated via technical and financial performance indicators.

Electric Distribution System Indicators

Project indicators reflect the fundamental characteristics of the rural electrification project, as presented in the form of energy and statistical data. If unexpected or extreme results are observed when applying previous survey data to the financial model, then the analyst should evaluate these data and their assumptions.

- *Energy requirements (MWh)* – The quantity of energy purchased or generated by the project to be commercialized to connected consumers over a one-year time period, equivalent to the service provider's total energy sales, plus energy losses; measured in megawatt-hours
- *Annual peak power demand (MW)* – Maximum power required to satisfy total consumer demand, usually measured over a 15-minute interval
- *Primary line (km)* – Number of kilometers of primary lines (high voltage, from the distribution grid) constructed and in operation, considered at year end
- *Losses (%)* – Ratio of energy commercialized to energy that is delivered to the electric distribution system through substation injection points. Losses comprise both technical and non-technical losses. Technical losses should not exceed 6-8% for urban distribution systems and 9-12% for rural distribution systems.
- *Collection efficiency (%)* – The ratio of total payment of energy bills to the total amount billed over a fixed period of time. Collection efficiency is one of the key performance indicators for electric distribution utilities. Efficiencies that fall below 90% can create huge financial burdens if not corrected in short order. Collection efficiency should be 95-98% in a well-run electric distribution utility.
- *Penetration rate (%)* – Percentage of residential, commercial, and industrial consumers connected

to the electric distribution system over the total number of potential connections

- *Population coverage* – Percentage of the area's total population served by year end

Financial Indicators

The following indicators are commonly used to evaluate investment viability. All values evaluate discounted net revenues or some derivative of net revenues, as indicated below.

- *Debt service coverage ratio* – Ratio of net revenue to debt service (interest on long term debt and principle payments)
- *Additional working capital requirement* – Amount of additional working capital needed to cover projected operating deficits
- *Internal Rate of Return on Equity (IRR)* – Standard measure of project financial viability reflective of the average annualized rate of return on equity generated by the project

CONCLUSIONS

This module provides an overview of the process of defining, designing, and analyzing rural electrification projects. While other modules in this series provide more in-depth descriptions of each individual process, this module integrates each individual step into a consistent whole, describing how each step fits into the project development process.

This final section on the project feasibility process summarizes the steps required for each phase of feasibility analysis. Feasibility studies include six components:

1. Definition of the project, including a summary of its scope and characteristics
2. Evaluation of the demographic characteristics of the project and the project area
3. Evaluation of the projected energy consumption and power demand over the life of the project
4. Analysis of the engineering characteristics of the project, including an evaluation of the substations and primary distribution line design
5. Economic evaluation of project costs and benefits
6. Final evaluation of project financial viability

The sections below summarize the steps required for each of these six studies.

Project Identification

The steps required to complete the process of project identification and definition include the following:

Define the scope of the project. Take into account local geography, topography, housing cluster density, and specific energy consumption, among other factors.

1. Determine the population served by the project, by utilizing census data or conducting a demographic survey of the project area.
2. Identify potential energy supply sources and select the most cost-effective and reliable resource.
3. Estimate the project cost by developing a preliminary project map, estimating line length and path and the approximate number of consumers using unit cost estimates for distribution system construction.
4. Estimate the number of beneficiaries.
5. Determine whether the total estimated project cost fits within the general parameters of the rural electrification financing program.

Demographic Evaluation

The demographic analysis allows the project team to ascertain consumption and load growth levels. The activities undertaken to complete demographic evaluations normally occur in this sequence:

1. Design and conduct a community survey. Its purpose is to profile economic and demographic characteristics of the community as a whole.

2. Design energy use surveys for both residential and commercial energy use within the surveyed population. Assure that all forms of energy are included in the survey, including electric and non-electric energy supplies.

3. Determine the sample size of the surveyed population for residential and other consumer categories.

4. Evaluate willingness to pay for electric service, making certain to survey for specific energy uses. The most frequently measured consumption type is illumination, due to its importance in residential energy consumption.

Electric system design also contributes greatly to infrastructure cost.

Demand Analysis and Projection

Evaluating the market for electric service is a fundamental task. Analysts must undertake this task with a comprehensive scope and with a sufficient degree of accuracy to ensure relevant results. Demand analysis and project require the following steps:

1. Evaluate the number of potential consumers through a survey or census. Classify consumers into customer categories such as residential, commercial, industrial, and other categories.

2. Estimate the likely penetration rate of consumers by category who are expected to connect in the first and subsequent years.

3. Determine the growth of consumers and growth in energy consumption for each project year. Take into consideration population growth rate and estimated growth of specific consumption per consumer.

4. Estimate energy consumption for public lighting, normally by assuming the number of lamps to be installed per km of line.

5. Calculate losses based upon historic loss levels, coupled with loss reduction measures. For new infrastructure projects, loss levels should not exceed 8% for urban systems or 12% for rural distribution systems.

6. Estimate total energy consumption by adding the estimated consumption for each consumer category, public lighting consumption, and losses.

7. Finally, determine the power demand projection, in kW, for each year of the analysis.

Engineering Design & Analysis

The design of the distribution system is a critical factor affecting overall sustainability, and project financial viability. Electric system design also contributes greatly to infrastructure cost. Therefore the project team must ensure that the design process includes engineering discipline and takes into consideration the long-term safety and security of consumers and utility staff.

The following are the required steps to assure proper engineering design and analyses:

1. Establish design standards. If standards have not already been adopted by a the utility or a national standards committee, project management should adopt a standard based upon internationally recognized best practices for design purposes.

2. Define final line routing. For ease of conversion to an engineering model, georeference the intended path of the electric distribution system with global positioning system receivers whenever possible. This process creates a

geographic information system with which to manage these data.

3. Convert the electric distribution system map to an engineering model. The engineering model should define the locations of distribution lines (with line lengths and impedances assigned), substation locations, distribution transformer locations (with load assigned to each transformer or line segment), and other line devices.

4. Evaluate load flows and voltage drop in the engineering model. This exercise adjusts the distribution system characteristics to maintain projected voltage levels within design parameters. Voltage should not drop more than 5% of nominal during any project year. If voltage drops exceed the maximum allowable values, the distribution system characteristics (conductor size, number of circuits, or configuration) may require adjustment to assure that power quality is not compromised.

5. After evaluating the system design and deeming it adequate, use the final design characteristics to estimate total system cost. The adjusted system cost should be used as the basis for the financial viability analysis.

Economic Analysis

Economic analysis evaluates the value of the project to the stakeholders' well-being. Economic benefits generally result from lowering the financial cost of service to some fraction of electricity consumers and improving the quality of service to all consumers. Rural electrification projects result in a wide variety of economic benefits, some not easily measured directly. The most common and most easily measured benefit, and therefore the most frequently measured benefit, is providing a lower cost and more reliable lighting service.

The most widely used method of evaluating potential lighting benefits is through a survey. The survey process evaluates the cost of traditional lighting sources and compares the cost and quality of light to the service that will be provided via a new electric grid. The steps required to evaluate the economic benefits of rural electrification projects therefore include:

1. Design and conduct an energy survey in the project area. The energy survey should include an evaluation of traditional energy sources, the economic activities that these energy sources serve, the level of energy consumption, and energy cost.

2. For each energy use (and corresponding economic activity), evaluate the comparative cost of the traditional source of energy per unit of consumption. Perform a comparative analysis of the traditional energy source to the cost of serving the same economic activity with electricity from the rural electrification project.

3. To the extent possible, and based on available data, determine the economic value of the project by summarizing benefits from each energy type (with corresponding economic activity) for each consumer category (residential benefits, commercial benefits, and industrial benefits).

4. As a means of evaluating pricing strategies, evaluate willingness to pay for electric service based upon the results of the survey data, including historic reported energy payments per energy unit.

Financial Analysis

Financial analysis is the final step in the process of project feasibility analysis. Financial analysis measures the commercial investment performance of the project. Such analysis evaluates the ability of the project to generate sufficient revenues to cover operating expenses, including debt service. The analysis may include an evaluation of the requirement for capital subsidies. However, this depends upon the opportunity to secure capital subsidies to buy down the cost of project implementation. The steps involved in performing financial feasibility analysis include:

1. Evaluate all costs associated with project implementation and electric service operation. Costs include, but may not be limited to, the cost of power purchased (or generated); salaries and contractor costs associated with operating the electric distribution system; debt service; rents; vehicular expenses; maintenance and maintenance materials costs; and other operating expenses.

2. Evaluate revenue streams derived from electricity tariffs; revenues from other services and fees assessed as a function of service delivery; interest and investment income; and other sources of revenues.

3. Evaluate net revenues for each project year.

4. Evaluate financial viability using one or more financial performance indices, such as internal rate of return, return on equity, net present value of revenue streams, or other measures of project financial performance.

Calculating Consumer Willingness to Pay for Electric Service and Economic Benefits of Electrification Projects

MODULE 6 OF NRECA'S TECHNICAL ASSISTANCE GUIDES

6

EXECUTIVE SUMMARY

Successful rural electric cooperatives and successful rural electrification programs have utilized different systems and methodologies to identify and prioritize project investments. Because electrification is highly capital intensive and financial resoures are finite, it is critically important to determine empirically which projects are technically and financially feasible. This requires applying a consistent methodology to analyze the proposed projects and prioritize investments accordingly. NRECA has developed an objective methodology to analyze and then prioritize electrification projects. This module illustrates the various steps and tasks involved in the application of this methodology.

From a broad perspective, this module contributes to a more objective classification of electrification projects so as to optimize the investment of development funds. More specifically, it provides a comprehensive guide on how to estimate consumer willingness to pay (WtP) for electric service and the economic benefits of electrification projects. The WtP study and the analysis of economic benefits are extremely important to determine the technical, financial, and economic feasibility of electrification projects, particularly in rural areas. The WtP studies use comprehensive surveys of households with and without current electric service to determine, in the most reliable way possible, their actual consumption of and expenditures on energy over a defined time period. The data collected from these household energy use surveys illustrate the consumers' "revealed" WtP for electric service. Likewise, the economic benefit to the consumer is calculated using the data compiled from surveys and other reliable sources. The economic benefit represents the incremental value of utilizing higher energy value and lower cost per unit of electric service in place of alternative energy sources such as: candles, kerosene lamps, and batteries for lighting and household appliances. Completing the economic benefit analysis can allow the electric cooperative, government and/or other interested party to prioritize investments. The analysis is also useful in determining whether a capital subsidy is required for the project to be feasible, and if so, its level and duration. Its principles complement and supplement the other tasks involved in rural electrification project analysis, including demand assessments, engineering design, and financial analysis. The combined results of these different analyses determine the ultimate feasibility of the project.

This module includes brief explanations and guidance to help the practitioner conduct an energy use survey, calculate consumer WtP for electric service, estimate the economic benefits of an electrification project, and present the results.

Provided for the reader are three examples to illustrate the details involved in the application of the methodology. Whenever applicable in a specific step, the module mentions tools that may facilitate the process. For example, NRECA has developed many survey instruments and an electronic calculation model/worksheet to determine the economic benefits of electrification projects. The module also mentions software programs that are very useful in data entry, management, and reporting.

The two fundamental concepts for this module are consumer willingness to pay and economic benefit. These concepts are defined as follows:

Because electrification is highly capital intensive and financial resoures are finite, it is critically important to determine empirically which projects are technically and financially feasible.

- *Willingness to pay:* The maximum amount that an individual indicates that he or she is willing to pay for a good or service.

- *Economic benefit:* The increased benefit that a recipient could receive from a proposed project compared to his or her present situation. In the case of an electrification project, it indicates the attributed benefit of the electric service in monetary units, versus the use of current energy alternatives.

When analyzing an electrification project, we must know if the consumer willingness to pay for electric service will be sufficient for the project to be financially feasible. A critical mass of potential consumers must be able to demonstrate that they have the means and willingness to pay a monthly electricity bill, which is calculated by multiplying actual electricity consumption in kilowatt-hours (kWh) by the electricity tariff rate. In addition, to justify the implementation of the project, the economic benefit to consumers over the life of the project must surpass the capital cost expended to develop it.

INTRODUCTION

Successful rural electric cooperatives and successful rural electrification programs[1] have employed a variety of different systems and methodologies to identify and prioritize project investments. Because electrification is highly capital intensive and financial resoures are generally finite, it is critically important to determine empirically which projects are technically and financially feasible. This requires applying a consistent methodology to analyze the proposed projects and prioritize investments accordingly. NRECA has developed an objective methodology to analyze and then prioritize electrification projects. This module illustrates the various steps and tasks involved in the application of this methodology.

[1]Barnes, Douglas, *The Challenge of Rural Electrification: Strategies for Developing Countries* (Washington, D.C.: Resources for the Future, 2007).

Reliable data on energy expenditures among potential consumers in a target project area are vital to ensure the accuracy of the willingness-to-pay (WtP) assessment and economic benefit analysis. This module explains how to obtain these data, calculate consumer WtP, and estimate the economic benefits of an electrification project. The financial feasibility of an electrification project depends in large part on the capability of a critical mass of users to pay a residential tariff that generates sufficient revenue for the electric cooperative to cover the costs of operating and maintaining the distribution system. A project whose financial feasibility is based on erroneous assumptions about consumer willingness to pay will not be sustainable. Planners can prevent this error by conducting an adequate consumer willingness-to-pay study in the target project area.

This module provides the experienced WtP practictioner with a practical manual for basic reference on WtP and economic benefit analysis. It also enables the neophyte to carry out a consumer WtP study and estimate the economic benefits of electrification projects using data compiled from field surveys and other resources. This module is not intended to serve as a reference on financial or statistical analysis of projects.

Essential Definitions

Readers will more easily understand and apply the guidelines in this module with the following definitions of key concepts in mind.

- *Economic analysis:* analysis that shows the economic feasibility of a project, from the perspective of the user as well as that of the host country.

- *Financial analysis:* analysis of financial feasibility, which illustrates whether the project will be profitable or not, from the perspective of the electric cooperative or utility that will execute and operate system.

- *Economic benefit:* the increased benefit that a beneficiary could receive from a proposed project compared to his or her present situation. In the case of an electrification project, this represents consumers' monetary benefit accruing to from the use of electricity when compared with their use of current energy alternatives.

- *Alternative sources of energy:* candles, kerosene, dry cell and car batteries, and other fuels and materials used as sources of energy for lighting and appliances in the absence of reliable electric service. Note: This module does not quantify certain common energy resources, such as biomass for cooking, for which electricity is not a direct substitute.

- *Demographic study:* the study of the project's target population to identify and determine distinct characteristics that would affect project feasibility.

- *Demand study:* in the context of an electrification project, this study determines the demand for the electric service that will exist in terms of number of users, amount of energy consumption, and power required. The aforementioned study includes an estimate of the initial demand, as well as projections for future demand.

- *Willingness to pay:* the maximum amount that a person indicates that he or she is willing to pay for a good or service.

- *Expressed willingness to pay:* the maximum amount that a person expresses that he or she is willing to pay for electric service, typically registered in monetary units/month, in response to a specific question.

- *Revealed willingness to pay:* the maximum amount that a person indicates that he or she is willing to pay for a product or service through their actual expenditures on alternatives or substitutes for the actual good or service in question. For an electrification project, this refers to a situation where electric service has limited hours or is subject to frequent and prolonged blackouts, requiring consumers to resort to alternative energy sources for lighting and other household energy applications. In such instances, the cost of alternative resources of energy and the cost of electricity (if the individual already receives some type of electric service) are included in the WtP calculation.

Purpose

This module contributes to a more objective classification of electrification projects, so as to optimize the investment of development funds. More specifically, it provides a comprehensive guide on how to estimate consumer willingness to pay for electric service and the economic benefits of electrification projects. Its principles complement and supplement the other tasks involved in rural electrification project analysis, including demand assessments, engineering design, and financial analysis. The combined results of these different analyses determine the feasibility of the project.

The content of this module will help the practitioner conduct an energy use survey, calculate consumer willingness to pay for electric service, estimate the economic benefits of an electrification project, and present the results. Incldued are brief explanations and guidance on the following 17 steps:

1. Identify the information needed.

2. Define the variables.

3. Formulate the necessary questions for the survey.

4. Design and test the instrument.

5. Design the database.

6. Define the target population.

7. Determine the size of the survey sample.

8. Establish a sample framework. and produce a map of the project area.

9. Select a random sample.

10. Instruct the enumerators.

11. Conduct and supervise the survey.

12. Enter, revise, and tabulate the data.

13. Analyze the data.

14. Calculate consumer willingness –to pay.

15. Calculate the economic benefits.

16. Present the final results.

17. Use the results in the technical and financial analysis.

It is important to demonstrate that the project's economic benefit is higher than the actual capital costs required to develop the project's infrastructure.

After reviewing the steps summarized above, the reader can better grasp the importance of synergy among the various tasks, such as harmonizing the database design with the survey instrument.

Whenever applicable within a specific step, the module mentions a few tools to facilitate the practictioner's task at hand. For example, NRECA has developed many survey instruments, including various financial models to determine a project's economic benefit to consumers. The module also mentions software programs like Epi Info, Microsoft Access and Excel, which are useful for organizing and analyzing data.

Global Perspective of this Module

This module was designed for use in developing countries. The concepts, terms, and methodology of this module are broadly applicable. Our wish is that it may be useful for experienced economists, as well as for those new to the use of willingness to pay and economic benefit analysis for electrification projects.

Although this module has broad application and NRECA has used this methodology in several countries, project analysts should always be careful to make the necessary adjustments for local conditions. Socioeconomic realities vary from one country to the next and from one project to the next. Practictioners must supervise and adjust the methodology's application to ensure results of the highest quality.

THEORY AND CONCEPTS OF WILLINGNESS TO PAY AND ECONOMIC BENEFITS

To justify the financing and development of an electrification project, the target population must demonstrate sufficient ability and willingness to pay for the electric service offered. It is important to demonstrate that the project's economic benefit is higher than the actual capital costs required to develop the project's infrastructure. The key concepts in such a determination are defined as follows:

- *Willingness to pay:* The maximum amount that an individual indicates that he or she is willing to pay for a good or service.
- *Economic benefit:* The increased benefit that a recipient could receive from a proposed project compared to his or her present situation. In the case of an electrification project, it indicates the attributed benefit of the electric service in monetary units, versus the use of current energy alternatives.

Willingness to Pay

Economists define "effective demand" as the demand for goods and services that are backed by the resources to pay for it. Consumer "effective demand" or willingness to pay (WtP) is determined through data acquisition and analysis from consumers in the proposed project area. Using interviews conducted in the field, analysts determine, in the most reliable way possible, the actual expenditures for existing energy sources, and other aspects of their economy that indicate the availability of resources to pay for the electric service. For an electrification project, data are collected from surveys and other reliable sources of information to determine, through empirical and quantifiable analysis, what a target population is willing to pay for the electric service.

For example, researchers ask the interviewees what they currently pay for alternative sources of energy like kerosene, candles, batteries, or for electricity in the case of communities already receiving some sort of electric service. This is known as "Revealed WtP" because it reveals what the consumer is actually paying for a good or service.

Researchers can also describe to the consumer a hypothetical electric service and then ask for the maximum amount they consumer would be willing to pay for such service. This methodology is known as "contingent valuation" because it implies the creation of a realistic scenario in which the interviewer offers the consumer a reliable electric service at a rational rate which is also feasible for the project. The method yields what is known as "Expressed WtP" because it reflects what the consumer expresses that he or she is willing to pay. This methodology can be very subjective and unreliable because the potential beneficiaries may not know enough about the service and its benefits to be able to offer a realistic response, or they may offer a high but unrealistic figure in the hopes that it might increase the potential for electric service.

NRECA uses both methodologies to determine the consumer's WtP. However, the Revealed WtP results provide preferable input for the project financial analysis because they reflect the consumer's actual expenditures on existing energy sources. The Expressed WtP is subjective, reflecting a consumer's perception of the value of the electric service. Nevertheless, it is useful as a basis for comparison with consumers' actual expenditures on energy sources, reflected in the Revealed WtP.

Economic Benefits

Multiple benefits result from the electrification of a community. NRECA's analysis of lighting cost and output across a variety of countries has unequivocally demonstrated that the provision of light via an electrical source provides exponentially greater lighting value at a fraction of the cost of traditional fuels and lighting appliances, such as kerosene lamps or candles. In addition to the visible and instantly recognizable benefits associated with cheaper and more efficient lighting, other benefits relate to education, health, entertainment and communication, comfort and protection, convenience, the environment, and productivity.

While empirical analysis has identified and quantified some of these benefits,[2] many of the benefits resulting from electrification are difficult and costly to quantify. Thus, not all of the benefits figure into the analysis described in this module. Although the methodology presented here is practical and sufficient to analyze and classify electrification projects, by no means does it capture all of the ancillary benefits of an electrification project. The NRECA economic benefit methodology is conservative in nature, and we acknowledge that the total project economic benefit may be much greater than the more narrow benefits quantified through this process.

This module describes how to estimate the economic benefit derived through changing from using alternative sources of energy to the use of grid-based electricity. Regardless of the source of generation, distributed electricity delivers a much greater energy value per unit at a lower price than any traditional energy source. (The units are the lumen for light or kWh for appliances.) This methodology quantifies the economic benefits the

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[2]See *"Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits"*, ESMAP Report 255/02, May 2002.

consumer receives when electricity substitutes for traditional energy sources like candles, kerosene, gas, and batteries.

First, analysts gather information on consumption and expenditures on alternative sources of energy among non-electrified consumers in the target project area. From that information, analysts calculate the individual consumer's economic benefit, which in turn helps them determine the overall economic benefit of the project. In some cases, economic benefit analysis also incorporates data and information on consumer expenditures and consumption of energy in communities that already receive electric service.

Important considerations within the calculation of consumer economic benefit are the costs associated with traditional fuels, in addition to the capital and maintenances costs for the appliances and equipment.

The total economic benefit for the consumer in communities without electricity is the sum of two related but independent calculations. The first only includes expenditures and consumption for household lighting. The second includes expenditures on, and consumption of, alternative sources of energy used for household appliances such as gas or kerosene refrigerators, battery-operated radios, or the associated costs necessary to acquire and operate a generator, among other appliances and power generation sources.

In isolated low-income rural communities, such as those found in the Department of Potosí in Bolivia, the project consumer's economic benefit is mostly associated with lighting. Electrical appliances are rare in such communities. Consumers might be spending money on biomass or propane gas for cooking, but for cultural and financial reasons electricity is generally not a direct substitute for these energy sources. Thus such expenditures are not considered when estimating consumer willingness to pay for electricity and determining the economic benefits of an electrification project. On the other hand, in some communities with more economic resources, such as in some parts of the Dominican Republic, many appliances and generators are in use, so that the economic benefit from other uses of energy could be higher than that for lighting.

Important considerations within the calculation of consumer economic benefit are the costs associated with traditional fuels, in addition to the capital and maintenances costs for the appliances and equipment. Normally NRECA does not obtain information on capital costs for small devices such as candleholders, lanterns, and lamps, which are assumed to cost less than US$20. For example, when using candles, the interviewer asks how many candles are used per month and the cost of the candles. The researcher does not ask the cost of the candleholders, assuming that these are sometimes not used or that they have little influence over the final cost of the candles. However, when dealing with an electricity generation system, or a backup system such as an inverter, small generation unit, or photovoltaic system that includes panels and batteries, the capital and maintenance costs can be significant and should be accounted for in any economic benefit calculation. The capital cost for small household photovoltaic systems ("SHS") could vary from US$250 to 2,500, depending on the size of the system in watts peak (Wp). In these cases, analysts normally use a "straight line" depreciation table that considers the lifetime of the equipment.

Economic Benefit for Lighting

The first step in the process of determining the lighting economic benefits of an electrification project is reviewing price data and consumption levels for traditional fuels used for lighting purposes. As previously explained, this is done through the willingness-to-pay survey. However, given that fuels are dissimilar, and that the amount of light generated from dissimilar lamps varies widely, it is necessary to convert lighting data to common units. Light intensity is measured in lumens, with light output expressed as kilolumenhours per month (klmh/month). The kilolumenhour (klmh) is a measurement of the value of light obtained from an energy source in an established period. The unit is a lumen. As an example, according to a study performed by the World Bank, a candle emits from 11-16 lumens, while a gas lamp has a range of 300-700 lumens.[3] The cost associated with lighting is expressed in cost per kilolumen-hours ($/klmh). After completing the cost analysis, the analyst can organize the cost data for easy comparison between the cost of electrical lighting and the cost of light generated by alternative lighting/ energy sources. Thus, it becomes possible to evaluate the financial or economic benefits for the two distinct alternatives in graphical form. The variables evaluated in this process include:

- The price of light produced (US$/klmh)
- The quantity of light produced for this priceper month (klmh/month)
- The price of light produced by using an electric lamp (US$/klmh)
- The electricity consumption associated with use of electricity for lighting purposes

Next, to the analyst graphs these values. Figure 1 illustrates a simple comparison of an electric lamp to a lamp using a traditional fuel, such as kerosene. It demonstrates the economic benefit accrued to the consumer who makes the transition from a traditional fuel and lighting source to electricity. The consumer pays a lower price, and receives more light at the lower price. The accrued economic benefit is called a consumer surplus. In Figure 1, it equals the area above the corresponding horizontal price line and below the demand curve. The consumer surplus represents the economic value received by the consumer through electrification at no additional cost.

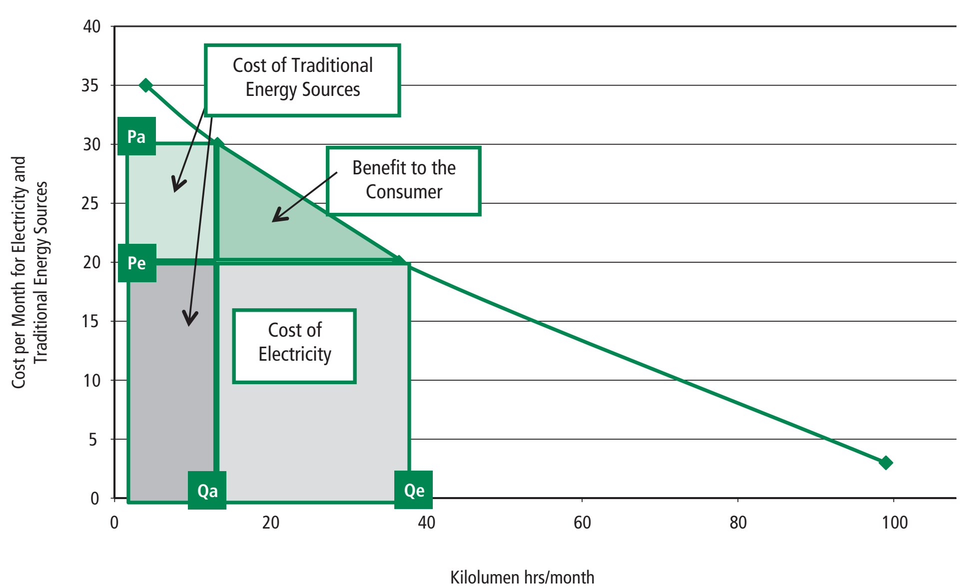
The monthly cost for alternative energy sources is represented by the rectangle (Pa * Qa). For an electrification project, the cost of electricity per month appears in the rectangle (Pe * Qe).

The data presented in the graph illustrate that electricity offers the consumer a more efficient lighting source, with a greater return, and at a much lower price, when compared to alternative energy sources. The surplus or benefit to the consumer is represented by the sum of the triangle

((Qe-Qa)*1/2(Pa-Pe)) and the rectangle (Qa*(Pa-Pe)).

[3]See Table A3.1 in Robert van der Plas and A.B. de Graaff, *A Comparison of Lamps for Domestic Lighting in Developing Countries*, (Washington, D.C., World Bank Industry and Energy Dept.: 1988).

Figure 1. Lighting demand curve.



Equation 1. Formula to calculate the economic benefit for lighting[4]

$D = Qa*(Pa-Pe)+((Pa-Pe)/2)*(Qe-Qa)$		
Where:		
Pe	Price of Electricity	US$/klmh
Pa	Price of Traditional Energy Sources	US$/klmh
Qe	Consumption of Electricity for Lighting	klmh/month
Qa	Consumption of Traditional Energy Sources for Lighting	klmh/month

The preferred methodology for determining the economic benefit associated with the utilization of electricity for non-lighting household applications is very similar to the methodology to calculate the economic benefit for lighting.

Equation 1 presents the formula used to determine the consumer economic benefit resulting from a switch to electricity from traditional lighting sources.

Equations 1, 2 and 3 present the specific formulas for calculating the consumer economic benefit that results from the switch to electricity for lighting and non-lighting applications, such as powering radios or televisions.

Economic Benefit from Other Energy Use

Two methodologies determine the economic benefit for energy use not associated with lighting. The first is based on actual expenditures on, and consumption of, traditional energy sources that are not associated with illumination. The second is based on electricity consumption for non-lighting purposes and the associated electricity tariff. The first methodology is more exact, precise, and analytically rigorous. However, it requires more data, effort, and time to calculate than the latter.

The project manager and lead analyst must decide between the two methodologies. To decide, assess the financial conditions of the communities, the data collected from expenditures and consumption of energy sources for non-lighting applications, and the level of detail required to justify the investment or to determine the level of subsidy. For example, the current energy use patterns in the Dominican Republic and Bolivia discussed above would point toward differing methodologies used for this phase of the economic analysis.

Methodology Utilizing Data on Actual Energy Use and Consumption

The preferred methodology for determining the economic benefit associated with the utilization of electricity for non-lighting household applications is very similar to the methodology to calculate the economic benefit for lighting. However, its unit of measurement is the kilowatt-hour (kWh), rather than the kilolumen-hour (used to measure lighting). The formula and methodology to calculate the economic benefit for lighting and non-lighting applications are the same – the only difference is in the units of measurement. For the formula to calculate the economic benefit for non-lighting applications, see Equation 2.

This methodology is relatively precise because it takes into account the actual operating cost and the energy consumption (in kWh) associated with household electrical appliances.

The use of this methodology depends on specific data obtained from household surveys on the

Equation 2. Formula to calculate the economic benefit for other uses of energy

$D=Qa*(Pa-Pe)+((Pa-Pe)/2*(Qe-Qa)$		
Where:		
Pe	Price of Electricity	US$/kWh
Pa	Price of Traditional Energy Sources for Other Uses	US$/kWh
Qe	Consumption of Electricity for Other Uses	kWh/month
Qa	Consumption of Traditional Source of Energy for Other Uses	kWh/month

Source: World Bank

[4]World Bank Report 255/02 "Rural Electrification & Development in the Philippines: Measuring the Social & Economic Benefits", May 2002.

energy consumption used for all household electrical appliances. However, this is neither simple nor straightforward, as each household often uses various types and brands of electrical appliances that consume energy from different sources. This can result in an enormous amount of information that requires great effort to compile, digitize, organize, and analyze. One way to reduce some of the required effort is to record all the household electrical appliances and hours of use per day, and estimate average power and/or consumption by appliance, rather than determining the actual energy specifications of each appliance and requesting specific information on its use within the household. The most precise way would be to write down the power of all the appliances, but such data are not always available. Instead, analysts can use an average of power for each device based on homologated charts.

This methodology is easier to apply in areas where consumers use only a few household electrical appliances. In Bolivia, NRECA's team used this methodology for the economic benefit analysis of communities in Potosí (the Tomoyo project) because the only electric device in frequent use was the radio, whose energy came from dry cell batteries. Not much time was required to calculate the average consumption and expenditures from one device and for only one energy source. Using the formula indicated in Equation 2, we were able to calculate the economic benefit of US$11.50/month for other energy uses for the Tomoyo project.

Methodology Using Data on Energy Use and Consumption in Similar Areas

An alternative methodology for calculating the economic benefit of energy use for electrical appliances utilizes recorded data on electricity consumption for non-lighting purposes in similar communities that are already electrified. Instead of recording actual consumption and cost of energy sources for non-lighting appliances, analysts simply multiply the kWh consumed for all non-lighting energy uses (including radios, televisions, irons, fans, etc.) in similar communities that are already electrified by the actual cost of power in US dollars per kWh. This formula appears in Equation 3.

This way of calculating the benefit of additional kWh consumption for other uses in non-electrified areas hinges on the assumption that if every individual is willing to pay for the electric service, then it is justified to assign a value at least equivalent to that of the prevailing retail residential electric rate. While this methodology does not necessarily capture the total economic benefit for non-lighting energy uses, it is still used as an easy and conservative way to determine at least part of the benefit.

For instance, if the total consumption of an average rural household is 50kWh/month and 20 kWh are used for lighting, the economic benefit of the additional 30 kWh used for appliances is estimated by multiplying 30 kWh times the residential retail electric rate. If the rate is US$ 0.10/kWh, then the benefit of the additional kWh is US$ 3/month.

In non-electrified areas where residents frequently use a variety of household electrical appliances and energy sources, the project managers must make an informed decision concerning the use of the two methodologies described above. They must carefully take into account the circumstances of the region, the time and resources available, and the precision of the data needed to make further decisions.

An alternative methodology for calculating the economic benefit of energy use for electrical appliances utilizes recorded data on electricity consumption for non-lighting purposes in similar communities that are already electrified.

Equation 3. Alternative formula to calculate the economic benefit of other energy uses

D = Pe* Qe
Where:
Pe = Price of Electricity (US$/kWh)
Qe = Consumption of Electricity for Other Uses (kWh/month)

Calculation of Total Economic Benefit

Calculation of total economic benefits simply requires the analyst to add up all the economic benefits generated by converting from traditional fuel sources to electricity. One way of presenting the economic benefits of electrification to a consumer is through monetary units per month. However, to estimate the maximum benefits that the project will generate, and hence, the maximum subsidy that should be considered for the project through capital subsidies, analysts should evaluate the net present value (NPV) of the economic benefits. Project teams may calculate the net present value by adding all the lighting and non-lighting benefits over the life of the project, and evaluating these benefits together as a single item. The net benefits are normally expressed as the net present value of the benefit stream.

NRECA makes the necessary adjustments to this basic methodology according to the existing conditions of the country, region, and the communities where the study will be conducted.

METHODOLOGY FOR ESTIMATING WILLINGNESS-TO-PAY AND ECONOMIC BENEFIT

We now turn to the methodology to conduct consumer willingness-to-pay studies and economic benefit analysis. While the methodology for both activities should be consistent and rigorous, conditions within the project's community dictate the details of its application. Flexibility may be needed to account for issues involving data, consumer characteristics, geography, topography, etc. NRECA makes the necessary adjustments to this basic methodology according to the existing conditions of the country, region, and the communities where the study will be conducted.

At the conclusion of a WtP and economic benefit study, the project team knows how much the target population would be willing to pay for electric service and what the estimated economic benefit of the project would be if it were developed. These dual goals drive all steps of the methodology.

Of course, the final results of the process depend entirely on the quality of the data collected and the precision with which is the data are analyzed. Errors can be made in determing appropriate sample size, recording data during consumer enumerators, or while transferring data from survey forms to an electronic database, etc. Errors made at any point in the process negatively affect the integrity of the results and could negatively affect decisions regarding project development.

Minimize errors by carefully determining the sample size and its randomization in the following ways:

- Closely following the field procedures for conducting consumer interviews
- Supervising the field work to ensure the gathering of the highest quality of data
- Conducting a careful data entry process
- Performing a detailed review of the database prior to analysis
- Verifying in detail the formulas and procedures for the data processing and analysis
- Reviewing the final presentation of results to ensure that it is error-free

The application of the methodology is illustrated through two projects: the Tomoyo project in Bolivia (a project with 600 consumers) and the Cooperativa Eléctrica Fronteriza (Fronteriza Electric Cooperative – CEF) project in the Dominican Republic (a project consisting of 17,000 consumers). Practical examples from other projects illustrate certain key issues, practices and/or results.

As part of a rural electrification program financed by the USDA, NRECA conducted a study of consumer willingness to pay and an economic benefit analysis of a potential rural electrification project planned for several communities in rural

Bolivia. The proposed project was located in Tomoyo, which borders the departments of Chuquisaca and Potosí, respectively, and which is north of the city of Sucre. The Tomoyo project would extend the existing electricity grid from the town of Potolo up to Llajtapata, resulting in electricity access for six communities with approximately 600 potential consumers. NRECA conducted interviews in each of the six communities located along the main project route, including Molle Molle 1, Molle Molle 2, Sorojchi, Yoroca, Tomoyo, and Llajtapata. Maps highlighting the Tomoyo project are presented in Module 5.

Researchers also conducted various field survey interviews with consumers in the town of Potolo, which already had electric service. Analysts used this information as a basis for comparing information on energy consumption and expenditures in the six communities that encompassed the project.

In a southwestern area of the Dominican Republic, NRECA conducted a consumer willingess to pay study and an economic benefit analysis of a proposed rural electric cooperative and electrification project. The proposed project included the communities of Las Matas de Farfán, Comendador, El Cercado, Hondovalle, Matayaya, El Llano, Bánica, and Pedro Santana—collectively referred to as the Cooperative Electrica Fronteriza (Fronteriza Electric Cooperative or CEF).

Identifying the Necessary Information and Questions

Since consumer WtP greatly affects the determination of project feasibility, it is important to verify its results using several tools. For the Revealed WtP, this includes gathering data concerning all current expenditures for energy sources that would no longer be purchased once the population has reliable electric service. For example, the survey would ask how much the household spends on candles, dry cell batteries, kerosene, and other liquid fuels for lighting. It would pose similar questions for consumption of and expenditures on traditional energy sources for appliances, including dry cell batteries or car batteries to power radios and small televisions, kerosene or propane gas for refrigeration, as well as diesel for water pumps, small portable power generators, and other internal combustion engines and equipment used for household or business purposes. The data on current expenditures for traditional energy sources used for lighting and appliances serve as an acceptable estimate of what that household could pay for electric service.

In addition to questions on consumer expenditures on traditional energy sources, it is useful to ask questions that might provide supporting evidence regarding whether the target population has enough income to pay for electric services. This could include questions regarding expenditures on other goods, such as housing, food, transportation, education, health, and telecommunications, such as cell phones. Data on expenditures for these types of goods and services could also provide useful indicators of how much the consumer or household would be willing to pay for electric service.

After completing a list of data requirements needed to determine consumer WtP, one can then focus on the data requirements of an economic benefit analysis. Based on Equation 1, the data required to calculate the consumer and project economic benefit would include the electricity tariff, along with the cost and consumption of traditional energy sources. Two methods provide for estimation of the electricity tariff. First is the use of a proxy tariff in an adjoining electrified village. Second is estimating consumer penetration based on consumer WtP and calculating a cost of service tariff that would provide sufficient revenue to cover the utility's operating and maintenance costs.

As previously explained, the four main variables used to calculate the project economic benefit (for lighting) are:

Pe = Price for electricity (US$/klmh)

Qe = Quantity of electricity (klmh/month)

Pa = Price of alternative energy sources (US$/klmh)

Qa = Quantity of alternative energy sources (klmh/month)

Estimates for consumption of electricity (Qe) can be determined by means of household surveys that collect data on electricity consumption in villages that are currently electrified and have similar socio-economic conditions to those prevalent in the proposed project area. A second method of estimating electricity consumption is through data provided by electric utilities that previously served consumers in the area. Survey questions ask about the use and type of light bulbs (incandescent or fluorescent, for example), as well as electric appliances. In addition, the researcher would ask to see electric bills from previous months to record the actual consumption of kWh/month. Whenever possible, obtain data on average electricity consumption for each user category (residential, commercial, industrial) from the electric utility that serves the project area. To standardize the data to determine the economic benefit, one must convert klmh/month to kWh/month using the conversion factor for both incandescent and compact fluorescent bulbs.

The data on current expenditures for traditional energy sources used for lighting and appliances serve as an acceptable estimate of what that household could pay for electric service.

To obtain values for the Pa and Qa variables, the practictioner needs to ask questions concerning the amount and cost of alternative energy sources. The examples below explain this process for a solid fuel (candle) and a liquid fuel (kerosene) potentially used for lighting purposes. Follow the same procedure to ask questions concerning any other alternative energy sources.

The data required to determine expenditures on, consumption of, and the energy value obtained from the usage of candles by a household require several interrelated questions. First formulate a question about the number of candles consumed in a finite time period, such as a week or a month, and then inquire about the cost of candles. We also want to know how many kilograms of candles are used per month so that we can convert that amount of weight into lighting value in klmh. The interviewees will likely not know the weight of the candles that they use for lighting, so the field supervisor would have to weigh the various candles sold in the community in a local store or market to determine the precise weight for each size.

For candles, obtain the following information:

- How many candles are used per time period (day, week, or month)?
- How much does each candle cost (US$/candle)?
- How much does one candle weigh (kg/candle)?
- How many klmh of lighting are obtained by each kg of candle (klmh/kg)?

With the information gathered from the questions above, we can calculate the Pa (price of candles in $/klmh) and Qa (consumption of candles in klmh/month).

For kerosene, obtain the following information:

- How many liters of kerosene are used per time period (week or month)?
- How much does each liter cost (US$/liter)?
- How many klmh of lighting are obtained per liter of kerosene (klmh/liter)?

With the exception of the final question in each set above, for both candles and kerosene all of the above data would be acquired through a household questionnaire. Data on the lighting value of various sources, including candles and kerosene, are obtainable through detailed academic studies.[5]

[5]See van der Plas and de Graaff, op. cit.

With field experience, the practitioner will come to realize that candles of different sizes are used in most rural areas of developing countries, so the questionnaire must be adapted to include all sizes. On the other hand, not all rural households use candles. The researcher can therefore save time by asking one question at the beginning of the section on lighting, for example: Do you use candles for lighting? If the interviewee provides a negative response, then you can skip to the next series of questions. A similar interrogatory framework applies for other traditional lighting fuels, such as kerosene for lamps.

After identifying the specific information required for project analysis, it is possible to define the variables, formulate the questionnaire, and then design the database to store and analyze the data to be collected.

One way to define questionnaire data variables for the corresponding database is by assigning acronyms from the words that describe the variables, such as:

- EWTP = Expressed Willingness to pay for electric service
- RWTP = Revealed Willingness to pay for electric service

Alternatively, one can assign names to variables according to the corresponding number on the questionnaire. For example, in the questionnaire for the CEF project, question 407 of the survey instrument related to expressed willingness to pay. This question was posed in the form of a bidding process, in which the interviewee would make a first offer and then the researcherr would raise the monthly cost up to a point at which the interviewee would no longer be willing to pay more for electric service. The final bid was then converted into U.S. dollars according to the prevailing exchange rate on the date of the survey. The variables used in the CEF database for these two questions were the following:

- Q4071ST = Question 407 the first offer in the expressed WtP auction
- Q4072ND = Question 407 the second (last) offer in the expressed WtP auction

To determine revealed WtP, one would add up all of the expenditures for all the alternative energy sources used for lighting and appliances for which electricity would immediately subsititute. As previously mentioned, we can assign names for the specific variables with letters taken from their names as follows:

- SCQT = Small candles, quantity/month
- SCP = Small candles, price
- SCCM= Small candles, cost/month = SCQT * SCP

Alternatively, the variables can follow the sequence of the questions on the survey instrument. For the CEF project, the question concerning small candles was No. 201. The designation for such variables in the CEF database was:

- Q201SC = Question 201 Small candles, quantity/month
- Q201SC1 = Question 201 Small candles, price
- Q201SC2 = Question 201 Small candles, cost/month = Q201SC * Q201SC1

In addition to the data requirements, it is also often important to obtain more subjective information by asking simple questions concerning the opinions held by the population. Examples include:

- *System technology.* What opinion do you have concerning electric meters? Do you trust that the meters are accurate?
- *Stakeholders and counterparts.* Who are the most respected leaders in your community, and who can be counted on to assist us in executing the project?

After identifying the specific information required for project analysis, it is possible to define the variables, formulate the questionnaire, and then design the database to store and analyze the data to be collected.

- *Public awareness.* What is your preference for receiving information about the project (radio, TV, newspaper, community meetings, or other means of communication)?

- *Institutional model.* Do you prefer a cooperative, government, or private institutional structure?

Designing and Testing the Questionnaire

A good questionnaire design not only prevents problems of interpretation and facilitates the flow of the interview, but also serves as a guide for the design of the database

After formulating the survey questions, organize them into a physical instrument. A written questionnaire records household information and data in an easy, efficient, and rigorous manner. A questionnaire not only provides a physical record of information gathered though field interviews, but also facilitates the transfer of the information to an electronic database for reporting and analysis. A good questionnaire design not only prevents problems of interpretation and facilitates the flow of the interview, but also serves as a guide for the design of the database and rapid transfer of printed information to the database itself.

The role of the enumerator, or interviewer, is to quickly and efficiently obtain information from the interviewee. The questionnaire acts as a guide for this process, and therefore must follow a logical, simple and direct format. With a well-designed questionnaire, the enumerator can write down the information quickly and conduct more interviews, while also preventing errors and confusion when the information is later processed. The information recorded in the questionnaire determines the quality of the WtP and the economic benefit analysis.

One basic survey design is the following:

- *General information.* The questionnaire begins with questions concerning general information, such as the type of consumer (residential commercial, or industrial), and other specific details such as number of individuals in the household, or type of productive use (mill, carpentry, store, etc.)

- *Information related to lighting.* To determine the Revealed WtP of the consumer, the questionnaire includes questions concerning the use of and expenditures on all types of alternative energy sources for lighting. This section includes questions concerning the use and size of candles, type and amount of fuel for traditional lamps, the type and amount of batteries used for flashlights, the use of solar panels, etc.

- *Information concerning other uses of energy.* This section of the questionnaire contains inquires regarding usage of alternative energy sources for household electrical appliances, such as car batteries that might be used to power radios and televisions. It may also include data on the consumption and cost of diesel fuel or gasoline for private electricity generators.

- *Expressed willingness to pay:* Normally this section of the questionnaire starts with a hypothetical scenario in which the interviewer asks the potential consumer how much he or she is willing to pay for a reliable and safe electric service and, through an auction/bidding process, determines the maximum amount that a consumer would express as their WtP for electrical service. A later section of this module goes into more detail on the proper method of conducting the auction/bidding process.

- *Consumption and cost of electricity.* To compare alternative energy sources and electricity, it is crucial to obtain information concerning consumption and cost of electricity. The section of the questionnaire containing questions related to electricity is for those consumers who currently have access to electric service, either in the target area of the project or in a similar socio-economic area. This information helps analysts estimate the consumption and cost of electricity for new consumers. It is also a key factor in estimating the potential demand for electricity from the project. In addition to data on consumption and cost of electricity, record consumer opinions on their current electric service and their perception of the quality of that service. In some systems, the consumer has a meter that bases their monthly bill on actual consumption. In other cases, the consumers do not have a meter, or the meter is broken, and they pay a fixed amount measured by "point loads" within the house, which normally are light bulbs or plugs. Another important aspect of the analysis of electricity consumption is its use within the home. Normally a home has several light bulbs for lighting, and depending upon the socio-economic level of the family, there might also be daily-use household electrical appliances, such as fans, irons, or a television set.

- *Income and expenses.* Data on the consumer's income and household expenditures allows the project team to calculate monthly household energy expenditures as a percentage of total monthly expenditures. In the majority of the rural areas where electrification projects take place, consumers maintain a fragile economic equilibrium that mostly depends on the harvest and sale of their agricultural products. Many try to supplement their agricultural income with other types of work, such as manual labor, or they receive income from family members that have steady jobs in a town, city, or foreign country.

- *Participation and disposition toward community organizations.* For electrification project planners contemplating some form of community-based or cooperative framework, it is useful to analyze and verify the presence of existing community organizations/cooperatives in the community, the level of participation of the consumers in these organizations, and their disposition towards these organizations as providers of the service.

In the case of the Tomoyo project, the demographic group leader designed the questionnaire using an examplar questionnaire that NRECA had formulated for other similar studies in Latin America. The team went over the questionnaire thoroughly and made adjustments to incorporate local terminology, the Bolivian currency, and other corresponding variables. Among other changes, they eliminated turpentine as a lamp fuel because it is not used in Bolivia, and substituted "wick" for the term "wick lamp."

Once the questionnaire is complete, it should be field tested. Although this could include trial field surveys in the project area, location is not critical in evaluating the instrument itself. No matter where it is tested, the draft questionnaire must be vetted to determine whether the questions that are posed are understood by interviewees, and to make sure it includes all the forms of energy that are used by the target population. The project team leader and staff should evaluate the questionnaire and make revisions based on information learned in the initial field trial before using it as part of a formal survey.

The draft questionnaire must be vetted to determine whether the questions that are posed are understood by interviewees, and to make sure it includes all the forms of energy that are used by the target population.

Designing the Database

Once the revisions of the survey questionnaire are complete, it can serve as the basis for the design of the electronic database that will compile the information recorded in the field survey. Carefully considering the information processing methods employed during the data entry phase contributes to the logical and simple organization of the database. Modifications to the design of the database based on changes to the questionnaire implemented while the field survey is in progress are permissible. For greatest efficiency, finalize the initial design prior to the commencement of field surveys, so as to speed up the process of transferring the questionnaire information to the database.

If the person designing the database has enough experience in database design, then he or she may proceed with the design. If not, the project team must hire external experts for the task. NRECA has used both options.

There are several types of software available for data management and reporting, and, in some cases, analysis. A common database program is Microsoft Access, which is part of the MS Office suite of software programs. Access can manage high volumes of data from multiple projects, as well as only a small data set from a limited field survey sample. Other software options worth considering include Epi Info, SPSS, or Microsoft Excel (for very small survey sample sizes), among others.[6]

The database for the Tomoyo project was designed in Excel because the sample included only 65 surveys. Normally such a database would be assembled in Access, Epi Info, SPSS, or another similar program.

Defining the Targeted Population

It is important to define the target population for the survey carefully, so that the fieldwork collects representative results from the population in the proposed project area. The target population for the survey is generally the population of the electrification project. However, surveys may sometimes be conducted within populations that already have access to electricity but fall outside of the proposed project to estimate potential electricity consumption and expenditures among consumers within the project area.

[6]Epi Info is a free statistics package developed by the Center for Disease Control (CDC) of the United States.

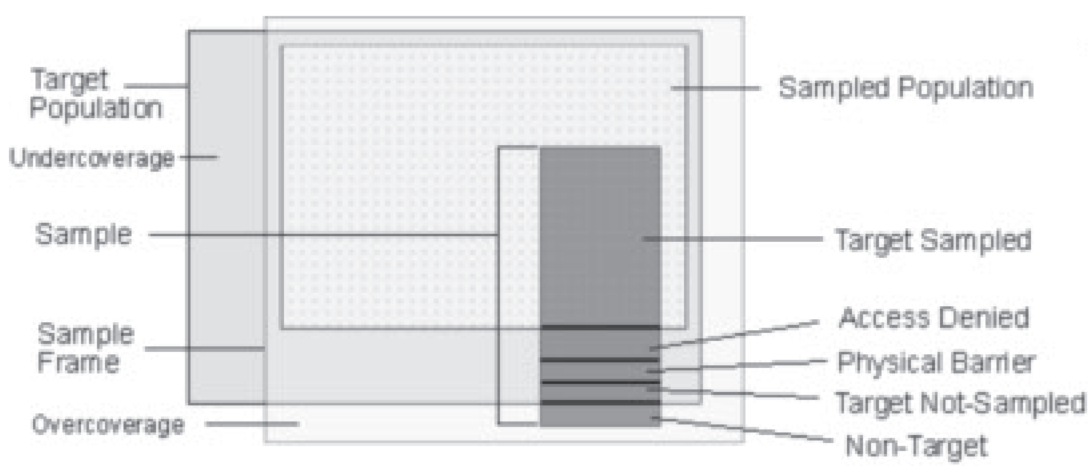
For the CEF project, the target population was all potential consumers who lived within the proposed area of service of the cooperative at the time the survey was conducted. Demographic data from the most recent census indicated that more than 21,000 families lived in the proposed project area. Not only would it have been very expensive to interview each of the 21,000 families, this is not actually necessary. To obtain data that is statistically representative, it is only necessary to interview a sample of the total population. Illustrated below is the sample frame for a survey, that is, a physical representation of the target population.

The relationship among the target population, the sample frame, and the sample can be appreciated graphically in Figure 2.

Setting a Sample Frame/Producing a Map of the Project Area

When electrifying small project areas, it is feasible to create a list, or map, of all potential consumers. However, for larger projects, such as the CEF, this data not only may not be available at the level of detail required, it would be too costly to obtain. Because the consumer survey generally covers the entire proposed area related to the scope of the proposed electric service, a general map can be used that does not go down to the level of households. Figure 3 shows the general map of

Figure 2. Relationship among the target population, sample frame, and the sample



Source: U.S. Environmental Protection Agency the proposed cooperative concession area that was used as the sample frame for the CEF project.

Figure 3 illustrates the extension of the proposed electrification lines of the CEF project. The project included locations in eight municipalities west of San Juan de la Maguana, from Pedro Corto in the east, up to the border with Haiti in the west, and from Pedro Santana in the north to Batista in the south.

A GIS was used to prepare the maps that are presented in this section. The target population can be subdivided using the GIS according to the criteria considered necessary or practical for the survey. For an electrification project in northwestern Uganda, the city of Arua was divided into seven specific zones, which encompassed areas with and without access to electricity, as well as a wide range of socioeconomic levels. The GIS helped subdivide area into the houses located in the city center, houses located 300 meters or less from the distribution grid, and communities more than 300 meters away from the grid. Surveys were conducted in eight different locations that represented a broad sample of socioeconomic conditions within the surveyed area. The black points shown in Figure 4 indicate the communities where household surveys were conducted.

Determining the Size of the Sample

The next step in the design of the survey consists in determining the size of the sample. The analyst must specify three key criteria to select an adequate sample size: the level of precision, the level of reliability, and the degree of variability.

The target population for the survey is generally the population of the electrification project.

Level of Precision

The level of precision, also called sample error or interval of reliability, is frequently expressed in percentage points. If a survey shows that 62% of the interviewees are in favor of a proposal, and the sample error was + or – 5%, then it could be concluded that in the entire population of the proposed area 57% to 67% of the population were in favor of the proposal.

Figure 3. Service area of the CEF project

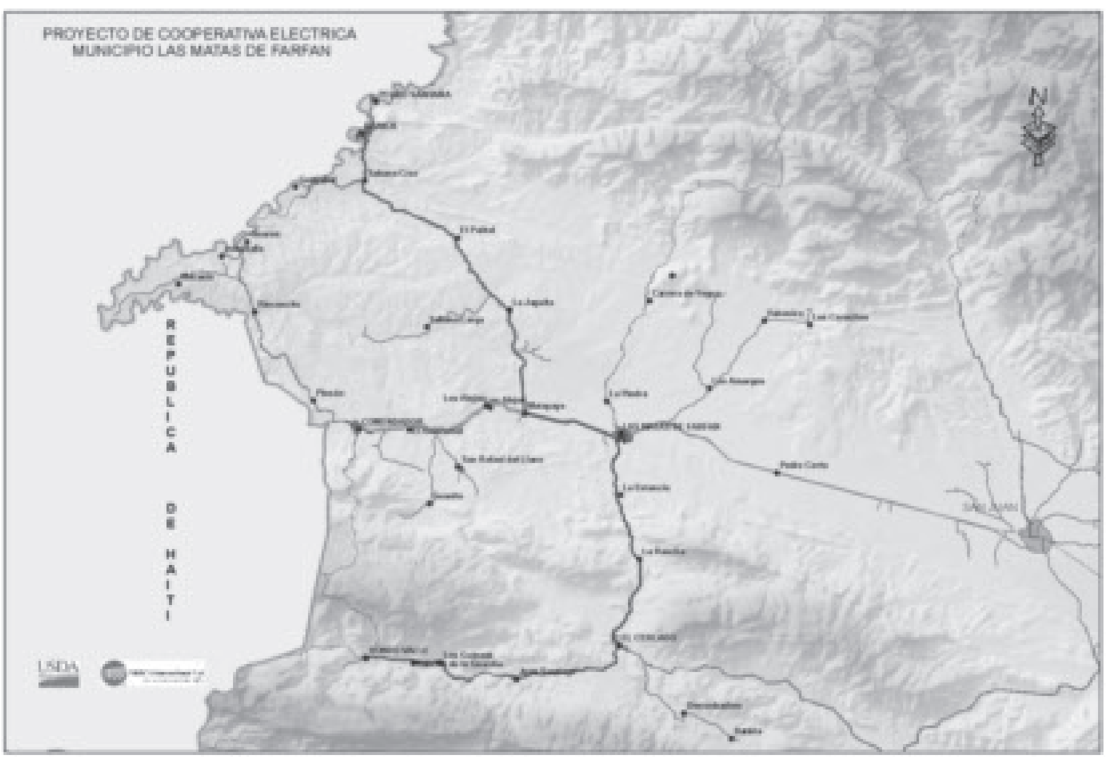
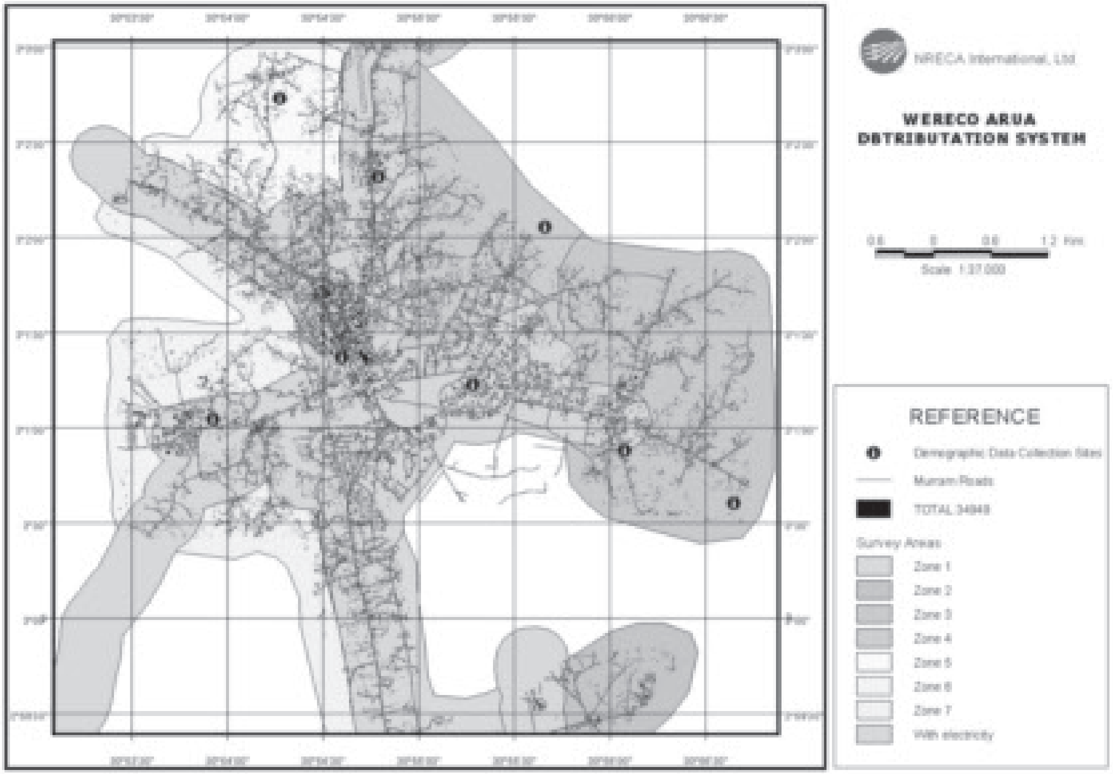


Figure 4. Map of surveyed area for the city of Arua, Uganda



The analyst must specify three key criteria to select an adequate sample size: the level of precision, the level of reliability, and the degree of variability.

Level of Reliability

The level of reliability indicates the degree of certainty of the results based on the principles from the Central Limit Theorem, which is the second fundamental theorem of probability. It states that the sum of a large number of independent and identically-distributed random variables will be approximately normally distributed (i.e., following a Gaussian distribution, or bell-shaped curve) if the random variables have a finite variance. Formally, a central limit theorem is any of a set of weak-convergence results in probability theory. In simple terms, a level of reliability of 95% means that 95 out of 100 samples reflect the real value of the population.

Degree of Variability

The degree of variability refers to the distribution of the population's attributes. The greater the variability, the larger the sample required. If the population is more homogeneous, then the sample can be smaller. A proportion of 50% indicates maximum variability. Thus, if the actual degree of variability is unknown, a conservative value of 50% variability is used to determine the size of the sample.

Strategies to Determine the Size of the Sample

With smaller populations, such as less than 100 houses, field workers should survey the entire target population. This is based upon two justifications. First, the main cost to conduct a survey is not the marginal cost of conducting a few additional surveys. Rather, the main costs are those associated with the design and preparation of the questionnaire, transporting the enumerating team to the field, and the data processing and analysis. Second, smaller populations require samples that include the majority of the population to obtain an acceptable level of precision. The formulas indicate that for a population of 100, a sample of

80 is needed for a level of reliability of 95%, an interval of reliability of + or – 5%, with a degree of variability of 50%. If the target population is of 100 or less, we therefore recommend interviewing everyone available. The cost of completing a few additional questionnaires is not significant, and the additional questionnaires help ensure a statistically valid analysis.

Another strategy to determine the sample size is to use the sample size used for similar studies. This approach is valid as long as the conditions are substantially similar and the previous study was statistically valid.

A third option is using published charts detailing valid sample sizes. There are charts available that have been prepared using formulas regarding valid samples sizes for various population sizes. To use such charts correctly, the user must fully understand the predetermined parameters upon which the charts were prepared.

Finally, several sample size-determining formulas exist. Equation 3 shows one such formula.

Equation 3. Formula to determine sample size of a large population of unknown total amount

ss = (Z^2*(p)*(1-p))/c^2

Where: ss = sample size

Z = Z value (for example: 1.96 for a level of reliability of 95%)

p = percentage that selects a response, expressed in decimals (.5 is the most conservative value)

c = interval of reliability, expressed in decimals (For example: .04 = ±4)

For example, when conducting a survey for an unknown population size with a level of reliability of 95%, and a level of precision of ±5%, calculation of the size of the sample is as follows.

ss = (1.96^2*(.5)*(1-.5))/.05^2 = 384

With a level of precision of 6%, instead of 5%, the size of the sample for an unlimited population size is 267.

In practice, NRECA has used a sample size of 300 for many surveys. A sample size of 300 is applicable for a maximum population of 1,376 people at a level of reliability of 95%, an interval of reliability of 5%, and a maximum degree of variability of 50%. However, if an interval of reliability of 5.66% is used instead of 5%, then a sample of 300 can be used for an unlimited population size. If the interval of reliability is maintained at 5% for a population of 100,000 or more, then a sample of 384 to 400 is needed, depending on the formula applied.

A sample size of 300 was determined for the CEF project. As mentioned above, for an unlimited population size, this results in a level of reliability of 95% with an interval of reliability of 5.66% with a degree of variability of 50%. To obtain at least 300 valid interviews, it is important to conduct at least 15-30 additional interviews beyond 300 to account for interview errors and other potential data faults. The final number of valid interviews processed for the CEF project was 302.

Selecting the Sample

The selection of the sample population is as important as the selection of the final size of the sample. The following example illustrates this point. Suppose we want to conduct a survey in a region of a country, and it has been determined that the size of the sample must be 300. If the field workers conduct all 300 interviews in the richest area of the most prosperous city of the region, then the results from the interview would not be representative of the entire region, even if 300 questionnaires were completed.

Some Sampling Methods

The methods for selecting a sample population so that it is scientifically representative of the target population interviewed include pure random samples and cluster or stratified sampling.

Many of the mathematical theorems concerning the discipline of statistics base their theories and methodologies on consequent suppositions within a randomly chosen sample. By definition, in a randomly selected sample each individual from the target population has the same probability of selection. When conducting field surveys for electrification projects it is often not practical, and in some cases it is impossible, to construct a randomly selected sample.

With smaller populations, such as less than 100 houses, field workers should survey the entire target population.

The CEF project used cluster sampling, in which the population is divided into groups and the groups are selected randomly. The groups in this case were the political divisions called "sites." Knowing that the project would benefit the greater population, all the sites of 200 houses or more were selected, along with a randomly selected sample of small sites. To obtain 300 surveys from the total population of the sample, it was necessary to interview an average of one out of every 43 houses. For the surveys in each site, the field worker would go to a central location in the community and select a random house for the first interview. After the first interview, the interviewer would advance 43 houses for the next interview. If no one was home or if the person did not wish to be interviewed, the researcher would go on to the next house.

If you know or suspect the existence of subgroups with very different circumstances or behaviors, then to preserve statistically representative conclusions, it is necessary to conduct a stratified sample. For example, this might apply if you wish to find the difference between those who receive an electric service with meters and those who receive electric service without meters.

In an electrification project's base case, where the communities have not had access to electricity previously, it is appropriate to conduct a random sample comprising of 300 surveys of non-electrified households. To obtain data on households that have electric service, the analyst must conduct another random sample of 300 surveys in a community with similar socioeconomic conditions. These two sample populations should not be mixed. For the CEF project, the target population had access to electric service but with frequent and prolonged blackouts. Under these circumstances, only 300 surveys were conducted because no nearby communities existed that experienced a similar lack of reliable and uninterrupted electric service.

Defining the Field Procedure for the Sample

After defining the target population, determining the sample size, and selecting the sampling method, it is time to define the method of selecting each house to sample. In the Uganda project highlighted in Figure 4, it was determined that there were approximately 35,000 inhabitants within Arua, Uganda. Demographic data indicated that each household comprised an average of six people, adding up to approximately 6,000 households within the target population. Thus, if the population of the survey consisted of 6,000 houses, and the size of the sample was to be 300, then the team had to analyze one out of every 20 houses in the population of Arua.

Tools such as GPS and GIS-based maps facilitate the selection process. These tools can define the number and location of houses in each area, and they can be programmed to select, according to pre-determined calculations, the house where an interview should be conducted. Thus, the analyst can avoid any prejudices or preferences in the field that may affect the results of the survey. Where there are no satellite maps to illustrate household-level detail, a standard print map of the area, together with demographic data (preferably from an official census), can be used in selecting households for interviews.

After determining a statistically valid method of household selection, begin conducting the field surveys by starting at a strategic point, such as the main plaza of the community and counting the houses one by one to determine which should be subject to an interview. For example, to conduct 25 interviews in a community that, according to the census, contains 462 houses, first randomly select a number between 1 and 19. Hypothetically, if the number 4 is selected then the enumerator would start conducting interviews begining with the fourth house and would then count 19 houses before knocking on the door to conduct another interview. If the owners of the house are not there, then the enumerator should simply proceed to the next house.

Because the communities that formed part of the Tomoyo project were very small, it was easy to select the sample. Each community was divided into different zones, and one member of the team conducted interviews in each zone. For example, a community of 80 houses was divided into four zones roughly equal in size. Within each zone, two or three interviews were conducted, with the houses in each zone selected at random.

Selecting and Training Field Workers

The field workers, or enumerators, are the ones who record the information provided by the interviewee onto the questionnaire. For the integrity of the data, qualified and competent enumerators must conduct the fieldwork.

When selecting enumerators, consider their previous experience in censuses and surveys, fluency in the language(s) spoken by the target population, clear penmanship, and willingness to travel and stay at the field location for extended periods of time, often under difficult conditions. Depending on the local culture and customs, the interviewing team should include both men and women. Often, suitable candidates arise through recommendations from the national state census agency, or via other academic institutions and non-governmental organizations that conduct surveys for their own purposes.

Clearly present all details regarding salary, travel expenses, and transportation to potential candidates during the interview process, as well as in any formal contract for services. In some cases, the enumerators receive pay for each questionnaire completed, and in others, they may recieve a daily rate for their work. An expert supervisor can determine which method is most convenient and suitable, given the circumstances.

During the preliminary selection of enumerators, include one or two individuals more than the amount estimated to be necessary to complete the work. The final selection of enumerators proceeds after observing how these individuals respond to the training and practice interview. It is always a good idea to maintain contact with least two alternate enumerators in case one or more of the selected candidates is not able or willing to participate.

It is important to adjust the training of the enumerators to the level of their previous experience. Fully review the questionnaire in at least one training session. During this session, the supervisor must ensure that all enumerators comply with the basic requirements needed to complete the work. Ask for feedback to ensure that the candidates understand the concepts and the vocabulary of the questionnaire. This feedback is also useful in setting the level of vocabulary used in the questionnaire for the target area. The training must include instructions on how to formulate questions in a direct and impartial manner. Bias on the part of the interviewer can greatly affect the responses they receive from their questions.

The questionnaires intended for communities that already have access to electric service contain specific details that are different from those for communities without electric service. What differs is a question concerning the consumption and cost of electricity. The enumerator should courteously request the respondent's last three electric bill statements in order to provide a verifiable record of past consumption and expenditures, rather than simply rely on consumers' memories for the same information. Be aware that a significant consumption variation could exist in regions with

If you know or suspect the existence of subgroups with very different circumstances or behaviors, then to preserve statistically representative conclusions, it is necessary to conduct a stratified sample.

a marked difference between the summer and winter seasons of the year. The enumerator must have the necessary training to be able to interpret electric bills and record the most significant data onto the questionnaire.

After completion of the design of the questionnaire and the theory portion of the training, the enumerators must conduct a field test. The field test helps project managers detect errors in the questionnaire or parts of it that are not clear. In addition, the field test demonstrates the enumerators' ability to perform the job.

It is not always convenient to conduct a field test in the proposed project area. If the cost of field testing is too high, the project planners may choose to perform the field test in a local area, or even in the training room. In this method, each enumerator is responsible for completing a trial questionnaire, preferably by interviewing a person who has never seen the questionnaire. This is not as effective as conducting the test in the field, but it can still provide useful results. The supervisors must pay special attention to the manner in which the enumerators conduct the interview, either in the training room or in the field, to evaluate their competence for the job. After the field test, managers modify the questionnaire and make the final selection of the enumerators.

For the CEF project, NRECA hired an expert in household energy surveys who had conducted similar studies for NRECA in the Dominican Republic. This field survey expert selected and supervised the enumerators conducting the field surveys.

Conducting and Supervising the Interview

Previous Preparations for the Field Work

Before conducting field work, project planners must interview and select suitable candidates to serve as field enumerators, prepare all of the materials required to execute the survey, and define the logistical details. The logistics make it possible for the field work to be organized and conducted within the time frame and budget established for the project.

Preparing the Materials

The survey supervisor is responsible for ensuring that all required materials are in order and ready to take to the field. These materials include an adequate number of questionnaires, pens, clipboards (so that the enumerators can write on the questionnaire), and paper or notebooks for taking notes.

The field survey supervisor should assemble and have ready at least 10% more than the minimum required quantity of questionnaires, so as to compensate for errors in printing or transcribing data. For example, if the sample size is 300 then there should be at least 330 photocopies of the questionnaire. Enumerators should always receive extra writing instruments to ensure that time is not lost while conducting interviews.

Provide the enumerators with some form of credential or documentation, such as a badge or hat, which identifies them with the organization conducting the interview. Do this only if it does not influence the results of the interview.

Prepare a list of equipment and materials for the entire survey group and for each individual. The equipment and materials may include maps, compasses, a GPS, a first-aid kit, communication equipment, sun block, mosquito repellant, umbrellas, a lantern, a pocketknife, and a camera. Besides the minimum materials required to conduct the interview, the field survey supervisor must ensure that enumerators are prepared for the circumstances they will encounter. For example, when conducting field work in a very remote area, it is important to take along enough food and water.

Logistics

The level of logistical complexity required depends on the location of the target population and the sample size. The location affects transportation needs and the time required to get to each sampled household. The size of the sample affects the number of enumerators needed to complete the work in the time frame indicated.

If all enumerators live in the city where their interview will be conducted, then transportation arrangements could be as simple as telling each enumerator where and when to show up to set out to conduct the interviews. On the other hand, if the project area is very remote, it will be necessary to coordinate one or more transportation options, such as plane, bus, 4-wheel drive vehicle, boat, or motorcycle.

In the past five years, NRECA has developed a standard methodology for conducting interviews with a size sample of 300 surveys. Questionnaires vary in scope and number of pages, but six to eight pages is common. Typically, completing a standard questionnaire takes 20 to 30 minutes. Add additional minutes for the time required in a certain community to advance from one interview to the next. On average, an enumerator can complete 12 questionnaires in one day. Five or six enumerators, with a supervisor, can usually conduct 300 interviews in five days. If the proposed project is in a remote area, additional time is required to arrive at the site of the project and then return to the base or main city.

One key aspect of logistics planning concerns funds or money management. Money is required for travel and other expenses, and it is important to purchase and account for all necessary equipment or materials required to complete the field work in a timely manner. Depending on the circumstances, it might be best to give the travel expenses to the field workers on the first day or leave this duty to the supervisors. Determine whether the field supervisor will have to carry cash or will be able to go to bank branches or other financial institutions for cash withdrawls.

Field Work

The design process of the interview and the preparation of questionnarie materials culminate with the field work itself. If the enumerators are sufficiently motivated, and conduct their work in an efficient manner, the quality of the data and thus the analysis will be much higher.

Completing the Questionnaire

The process of filling out the questionnaire can appear simple and easy. Even though the design of the questionnaire helps the enumerator conduct the interview, there are many opportunities for mistakes when recording response information. Each interviewer has his or her own way of writing, and in some cases, the questionnaire uses a language they are less familiar with. The enumerator also has the difficult task of trying to maintain the flow of conversation over the course of the interview, while recording the data and responses given by the interviewee. It is essential to emphasize the importance of extreme care while recording the data obtained during the interview.

After completion of the design of the questionnaire and the theory portion of the training, the enumerators must conduct a field test.

Enumerators must use clear penmanship that is easy to read. With predetermined codes and shorthand, the enumerators may avoid having to write as much text. For example, instead of writing “four liters per day”, it would be faster and to record “4 l/d”. It is also vital that the enumerator write down the interviewee’s actual response and avoid the temptation of performing mental calculations to convert the data, for example electricity consumption over time. Finally, it is important to take physical care of the questionnaires so that they are not lost, damaged, or destroyed. The response information is useful only after it has been properly recorded on the questionnaire and entered into the database.

Tasks of the Field Supervisor

The field supervisor has several key responsibilities throughout the field survey process. For instance, the supervisor serves as director of the team of field workers. In this role, he or she is directly responsible for ensuring good performance by motivating the team to work in an efficient, responsible, and rigorous manner.

The supervisor must establish a solid professional working relationship with the research team, based on mutual respect and trust. The supervisor can improve performance and motivation by establishing an esprit de corps, which emphasizes the importance of their work for the project and acknowledges their effort and diligence at the end of each day when the day's goals have been achieved.

The supervisor must review the completed questionnaires each night to ensure that the enumerators are completing the questionnaires correctly, that the information recorded is legible, and to clarify any discrepancies.

The field supervisor must accompany each enumerator at least once to review the way in which he or she conducts the interview. The supervisor must also meet with the enumerators as a group or individually to review the questionnaire, clarify any questions they might have, and respond to comments from the enumerators on any topic related to the field work. The supervisor must review the completed questionnaires each night to ensure that the enumerators are completing the questionnaires correctly, that the information recorded is legible, and to clarify any discrepancies.

While surveying the community, the supervisor must take systematic notes concerning general infrastructure and development, such as home construction, the local economy (commercial activity, agricultural products, etc.), and road quality and distance from other communities. It is also the responsibility of the supervisor to ensure that someone visits local stores or marketplaces to verify the local measurements and prices of alternative energy sources. For example, the supervisor must find a well-calibrated scale to determine and record the weight of the different available candle sizes. In addition, the supervisor must investigate whether the local custom is to use uncommon units of measurement, such as "bottles" or "cans" instead of liters or gallons. Otherwise, the enumerators may not be recording one "bottle" of kerosene as a liter without verifying how much kerosene is actually in a bottle of that size.

Interviews with Leaders of the Community

While the enumerators conduct their surveys within the assigned community, the supervisor must locate and meet with the local community leaders (mayor, council-member, sheikh, or village elders). During these meetings, the supervisor must clearly explain the purpose of the survey and their duration within their community. In small communities, the supervisor must often request the support and help of the local leaders to encourage the community to participate with the survey and enumerators. Besides explaining the project, the supervisor must conduct a survey of the community with the local leaders to acquire information concerning the local economy, migration patterns, productive uses of electricity (active or latent), community organizations, public services (schools, health clinics, etc.), and other relevant information.

Residential Interviews

For most rural electrification projects, the majority of interviews conducted on energy use and WtP involve community members. The supervisor and the enumerators must consider the times during which key individuals will be available for interview. For example, in many rural areas, farmers leave early in the morning to tend to their crops, while in more urbanized areas people will leave for their jobs later in the morning. Thus, during normal business hours many people will not be at home, and the supervisor must adjust the survey work schedule accordingly.

The start of the residential interview process begins at the respondent's door when the enumerator greets the residents and asks permission to enter their property or their home. After entering, the enumerator must greet and/or introduce themselves again, showing respect in a manner that is locally accepted (for example, with a verbal greeting of gratitude, hand signal, handshake, etc.). The enumerator must provide a clear and brief introduction of the project and explain the purpose of the interview. The enumerator should emphasize that there is still no commitment to complete the project, and that the decision to implement a project would depend greatly on the data acquired during the various interviews conducted within the community. The enumerator must never provide false expectations, regardless of the data that might encourage.

The interviewer should then answer any questions that the interviewee might have, then initiate the interview. For the section concerning lighting with alternative energy sources, the enumerator must request to see the candles and lamps used and the typical container used to store fuel such as kerosene. If the home utilizes solar panels, the enumerator must record the brand name, capacity, the number of modules, and the number and type of batteries used within the system. Concerning the use of energy for household electrical appliances, the enumerator must try to record the watts of power for each appliance. This information will determine their kWh consumed per month. If the household uses a private generator, then the enumerator must ask permission to inspect it. Then, he or she must fill in the corresponding section of the questionnaire regarding the generator's brand name, capacity, type of fuel used, cost of maintenance, the amount of hours per day during which it operates, and above all, the amount of fuel used per time period (e.g. 10 liters/week).

In the Expressed WtP section of the questionnaire, the enumerator should describe a scenario in which the household receives reliable and high quality electric service. Following this hypothetical scenario, the enumerator then seeks to determine by means of an auction or bidding strategy the maximum amount that the consumer would be willing to pay for such electric service. There are two ways of conducting the bidding. The enumerator can propose a maximum monthly price for the electric service. Then, the interviewee can accept the price, or if he or she refuses, the enumerator would lower the price in increments until the potential consumer accepts it and therefore indicates the price that he or she is willing to pay for electricity. Alternatively, the enumerator could start the "offer" at a very low monthly price and then increase the price until the interviewee closes the offer, indicating the maximum price that he or she would be willing to pay for electricity.

This same section of the questionnaire usually includes the Expressed WtP for the consumer's connection costs. In most rural electrification projects, the consumer pays for some or all of the connection costs to their house, which includes the cost of the meter, other related devices, and the physical installation of the service. The enumerator uses the same bidding or auction strategy described above to determine the maximum amount that the consumer would be willing to pay for a connection, either as a one-time payment or as a monthly fee, imposed over a defined period of time (e.g. US$3/month for 36 months).

For most rural electrification projects, the majority of interviews conducted on energy use and WtP involve community members and their homes.

To determine the consumer's income and expenditures in a clear and detailed manner, the enumerator must ask questions concerning several sources of income, such as agricultural products that are sold (including the amount and price received), and the typical expenditures of the family, such as food, school registration, clothing, transportation, etc. In many cases, consumers in rural areas purchase their food supply and essentials at traditional markets and weekly fairs. If the interviewee does not know the exact amount of the expenditures, then the enumerator could reach an estimate of their monthly expenditures by asking for the total expenditures for purchases at each fair.

If the house already has access to electricity, then the consumption and cost of electricity can be arrived at from the household's electric bills. The enumerator must try to examine at least three past monthly bills and record the data in the appropriate box of the questionnaire, keeping in mind any potential seasonal fluctuation in electricity consumption. The enumerator must also record the watts of power of all light bulbs (both incandescent and fluorescents) and household electrical appliances, and the number of hours per day that they are used.

Productive Use Interviews

Almost every community contains several types of energy consumers. Although the majority of consumers are households or residential users, small businesses and/or small industries are generally large consumers of energy. We call the latter types of energy uses "productive uses" because they consume energy to provide services or make products. A "productive use" is any use of electricity that generates income for the user, such as mills, stores, restaurants, sawmills, mechanical shops, and tire repair shops.

The enumerator must never provide false expectations, regardless of the data that might encourage.

The enumerators must receive training on how to identify productive uses and how to conduct productive use interviews. Whether through electricity or alternative energy sources, productive uses consume much more energy than does a typical residence. In addition, they provide a source of employment for the community and income for their owners and employees.

The interviews for productive use respondents follow the same format as a residential interview. However, field workers must understand the importance of recording the data related to fuel consumption and electricity. These data greatly influence the estimate of the potential demand for electricity and the potential income to the project. The enumerators must acquire reliable data about the equipment used for the different processes, and above all, the fuel consumption for any portable power generation units or other equipment in use.

Entering, Revising, and Tabulating Data

After the supervisor has verified the completed questionnaires, the data contained on the print version of the questionnaires are transferred to the database for processing, reporting, and analysis. This section how to enter, revise, and tabulate the compiled data from the questionnaires.

Completing and Cleaning the Database

This section describes the physical process of transferring data from the questionnaires to a computer database. However, we recommend that those in charge of handling the data keep up to date with the latest advances in automated data recording methods and equipment, such as equipment that reads the data directly from the questionnaire. As such equipment enters the market, it will help reduce the time necessary for data entry, as well as the number of errors in data transcription.

In some instances, one person might be able to complete the process of entering data. However, in most cases, it is helpful to have a team of at least two people. Regardless of the number of people involved in data transcription, there are certain steps required to transfer the data from the questionnaires to a computer database. These steps include:

- the organization of the questionnaires so that the data can be easily and efficiently transferred to the computer
- identifying and hiring one or more transcribers
- ensuring the availability of computers and adequate software
- the data entry process itself
- cleaning of the files
- making one or more back-up copies of the master document and other vital documents

The computers and software used for data entry must be compatible with the software used for data processing and analysis. One detail that could influence the efficiency of data entry is the design of a data entry file. A file programmed to detect errors and to skip automatically to the next field can speed up the data entry process.

Ideal transcribers are individuals who can enter the data quickly and without errors. The transcribers must receive training to know what to do when questions arise, when information is missing on the questionnaire, or when it is hard or impossible to read the response. For the CEF Project, NRECA hired transcribers, but for the Tomoyo project, given the small size of the sample, the local NRECA team entered the data. One member of the team read the information while another member entered the data into the Excel database.

The first step in data review and revision is to make sure the transcribers have verified all of the information entered. The contracts for transcribers could include fines for errors or simply state that they will not be paid unless the database contains no errors.

After entering all data from the questionnaires into the database, the supervisor must perform a detailed and systematic revision of the database. To verify the data, the supervisor can randomly select a percentage of the questionnaires to review. Then the supervisor would compare each entry in the database to the answer on the questionnaire. If the percentage of errors is greater than the minimum acceptable, then the entire database must be rejected, with the contractor or transcriber instructed to start the process of data entry again from the beginning. The CEF project had to follow this procedure.

After verifying that the information in the database exactly reflects the information recorded on the questionnaires, the supervisor must perform another level of revision. This task includes eliminating data that contain errors that are obviously out of the reasonable range of the dataset. Only an expert with the adequate experience required for this delicate task must do this. For example, the project manager might decide to eliminate an entry of 12,000 entered into the field that corresponds to a question regarding how many small candles a family uses per month. If the range of responses to this question in the rest of the database is between 2 and 100, 12,000 would clearly be an unrealistic response.

Data Processing

Once the entering of data into the database is complete, data processing begins. This involves applying formulas to obtain sums, averages, frequencies, percentages, etc. It might also involve programming the database to reorganize the data in an ascending or descending manner or presenting the data in a graph or table. The goal of reorganizing, categorizing, or processing the data is for an expert to analyze and to interpret the data and recommend actions according to the results of the analysis.

Sometimes the expert in charge of the interview performs all the data processing. Other times, he or she prepares detailed instructions for programmers to process the data, so as to obtain the necessary results for the next steps of the analysis. The analyst can study the results of the processing, look to see whether anomalies or outliers are present, and determine whether further assessment of the database is necessary.

Analyzing and Interpreting Data

The next phase of data analysis and interpretation is important because its results become inputs for the economic benefit analysis and financial projections, as well as providing estimates of the total demand of electricity in the project area.

The person who performs the data analysis and interpretation should ideally have a reasonable amount of experience and expertise gained from similar assignments. If the analyst does not have experience in data analysis and interpretation, he or she should work with an individual with experience in the matter until acquiring a minimum amount of experience.

A "productive use" is any use of electricity that generates income for the user.

It is important not to allow biases, preconceptions, or premature conclusions to influence the analysis. The Expressed WtP, for example, in theory reflects what a consumer would be willing to pay for the electric service. The analyst could infer that if the consumer understands what reliable electric service is, the consumer should logically be willing to pay more for electricity than what he or she pays for non-electrical energy sources. Nevertheless, this is not always the case.

The goal of reorganizing, categorizing, or processing the data is for an expert to analyze and to interpret the data and recommend actions according to the results of the analysis.

In some instances, consumers indicate that they would be willing to pay more than what they normally spend on alternative energy sources, while others respond to the enumerator's auction strategy by indicating they would be willing to pay less than what they currently spend for alternative energy sources. The latter response seems counter-intuitive, but it could indicate that either the consumer does not know exactly what he or she spends on alternative energy sources, does not understand the scenario described by the enumerator concerning the electric service, or simply does not value electric service as an important good or service.

If the results from the interviewees' Expressed WtP are less than the expenditures for alternative energy sources, then the strategies used for the interview must be reviewed, as well as how the enumerators described the electric service to the interviewees. On the other hand, if the Expressed WtP results are much higher than the Revealed WtP, the analyst must compare the Revealed WtP with the consumer's income. If the consumer indicates that he or she is willing to pay much more than what he or she presently spends on alternative energy sources, but the data on their income does not support such a WtP, then the analyst must consider the validity and applicability of the consumer's Expressed WtP. The consumer may clearly indicate the will and desire for electric service by indicating a high WtP, but based on his/her income there would be no way of ensuring payment for the service. The analyst must look for such results that are out of the range of feasible results, both for specific cases (individual consumers) as well as for the results in general. In cases where the answers do not make sense, the analyst must compare the data with the actual questionnaire and discuss it with the enumerator, if possible.

It is important to study the ranges of the results, starting with the Revealed WtP, and specifically with the expenditures and consumption of alternative energy sources used for lighting, to determine whether they are consistent with similar projects and known generalities.

Depending on the community's socioeconomic profile, the results of consumption and expenditures for alternative energy sources for other uses could reflect very low levels of consumption, such as in the Tomoyo project in Bolivia, or very high consumption, which occurs in parts of the Dominican Republic. Unless the interviewees are extremely poor, a majority of rural households typically have at least a small radio, used for basic entertainment and information. These radios use batteries of different sizes. Some use two type "AA" batteries, while a larger portable sound system could require the use of four to six of the largest size, type "D" batteries. The use of dry cell batteries normally represents a significant expense for the interviewees, both because they have a high cost per unit and because they do not last very long if they are used for powering a radio for several hours every day. In spite of their cost, frequently individuals are willing to buy dry cell batteries because they place a high value on entertainment and information. In economically marginal areas, there is typically little use of portable power generation units because very few people have the capital to purchase one, much less the income necessary to pay for fuel and maintenance.

Information concerning the consumer's income and expenditures can vary, especially in rural areas where the rural population consumes some or all of their agricultural harvest. In such cases, segregate agricultural product income from other sources of income, such as manual labor, sale of products, income received from family members in a foreign country (remittances), etc. The questionnaire also contains a list of all expenditures for products and services. The analyst must use the data related to income and expenditures cautiously, especially if there is evidence of a distortion of reality due to factors such as the following:

- The interviewees do not have a clear idea of what they earn or spend.
- They gave out wrong information or information that does not make sense.
- They refuse to give out information for any reason.

In such cases, the results must be purged and considered unreliable. When a consumer's reported income is high, confirm that the consumer's expenditures also correspond with this income. Generally, there is a direct relationship between income and expenditures for energy sources, and if the income is much higher than average, the expenditures are normally above the survey's average as well.

When attempting to record actual electricity consumption and expenditures from households that are already electrified, enumerators may find that the consumers do not have past electric bills available. If this occurs, results could be subject to distortions due to insufficient information. Another obstacle in the way of reliable results occurs where electriticity consumption is estimated rather than metered by the company that manages the distribution system. In such cases, it is essential that the analyst compare the consumption shown on the past electric bills with the consumption estimated by counting light bulbs, household electrical appliances, and hours of use. In this manner, it can be determined whether the estimated consumption shown on the electric bills is reliable or not.

The range of electricity consumption varies greatly according to the area in which interviews are conducted. For example, in marginal rural areas of Bolivia where the use of household electrical appliances is very low, an average consumption of 25-35 kWh/month is normal, while in rural areas that exhibit a higher socio-economic profile, as in the Dominican Republic, the average consumption is approximately 130 kWh/month.

For the Tomoyo project, the NRECA team leader analyzed the database to determine whether the data were far out of the established ranges and whether there were gross errors in transcription or other related problems. The team leader examined expenditures for different energy sources as well as total expenditures to determine consumer WtP for electricity. The data clearly indicated that the majority of the consumers had low incomes. It also indicated that the majority consumed kerosene for lighting, and had a portable radio to listen to the news and other programs. There were no other electrical appliances in use in these communities, nor were there any portable generation units.

It is important not to allow biases, preconceptions, or premature conclusions to influence the analysis.

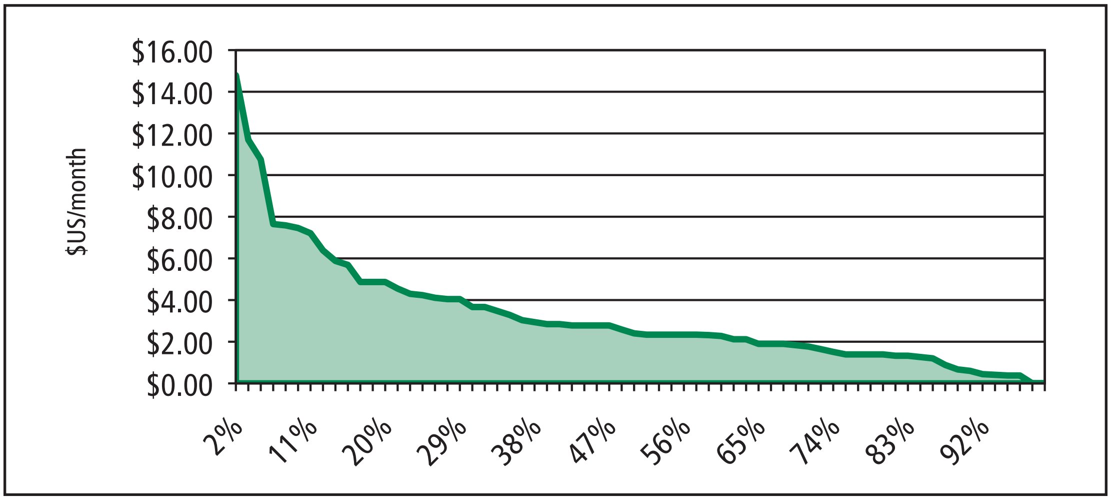
Calculating Willingness to Pay

The data concerning willingness to pay must be processed in such a way that the results can be presented not only as an average but also as distribution curves or charts with ranges.

Calculating Expressed WtP is as simple as applying the formula to obtain the average to all responses to the question of how much each person is willing to pay for the electric service. The CEF project had an average expressed WtP of US$ 7.63/month for the last offer from question 407. However, to better understand the economy of the target population it is useful to present the WtP results in the form of a distribution curve as observed in Figure 5 for the Tomoyo project.

To process the Revealed WtP data, the analyst concentrates on one energy source at a time, and converts it to a common unit of measurement, such as $/month spent for each energy source. Then the

Figure 5: Revealed WtP – Tomoyo Project



Generally, there is a direct relationship between income and expenditures for energy sources, and if the income is much higher than average, the expenditures are normally above the survey's average as well.

analyst can obtain the sum of all the expenditures for each energy source. Table 1 illustrates this procedure for small candle consumption within the CEF project. To begin, the amount of small candles used in each household was multiplied by what the interviewees indicated was the unit price per candle. Then, an average of the results was taken. On average, each household spent US$ 2.31/month on small candles, as indicated in Table 1. The analyst then calculates each other energy source in the same manner to obtain its expense per month. (Be careful not to multiply the average of the amount of an energy source by the average of its unit price. The result obtained from multiplying averages is not the same mathematically as the average expense calculated per household.) Figure 5 shows the Revealed WtP for the Tomoyo project.

Calculating Economic Benefits

In this section, we apply the basic theoretical concepts described earlier in this module to estimate the economic benefit of an electrification project. The first step is to add the economic benefit for lighting and the economic benefit for the energy consumed by electrical appliances. Then, to estimate the total economic benefit of the project, simply multiply the economic benefit of one average consumer by the total number of estimated consumers for the project. To express the economic benefit in terms of the scope of the project analysis, the net present value (NPV) of the benefit is calculated. The net present value is defined as the total present value of a time series of cash flows. It is a standard method for using the time value of money to appraise long-term projects. Used for capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows, in present value terms, once financing charges are met.

Taking the analysis one step further, the NPV of the economic benefit of the project indicates a limit to the acceptable level of subsidy for the implemention the project. In economic terms, there would be no point in implementing a project whose subsidy would be greater than the NPV of the total consumer economic benefit.

At a glance, calculating the economic benefit seems simple because the formula requires only the price and quantity of electricity (Pe and Qe), and the price and amount of alternative energy sources (Pa and Qa). However, the calculation usually becomes tedious because there are many alternative energy sources, and the data for each must go through processing and conversion. We now provide an explanation of how each variable is calculated.

Price of Electricity (Pe)

The electricity price for the CEF project was taken from the tariff specified by the government of the Dominican Republic when the financial analysis was performed. On that date, the electricity tariff for energy use was US$0.121/ kWh, with an additional fixed or demand charge of US$2.10/ month. Based on an average consumption of 133 kWh/month, this results in a tariff of US$0.137 /kWh. Dividing the tariff in US$/kWh by the conversion factor of 5 klmh/kWh for alternative sources of energy, the electricity price obtained was US$0.027/klmh.

Quantity of Electricity (Qe)

An estimate of the quantity of electricity (Qe) consumed by the average consumer can be obtained by gathering data on consumer demand for electricity in electrified communities that exhibit similar socio-economic profiles as the proposed project. The data compilation uses billing records from the electric company, consumer electric bills, and asking questions concerning the amount, watts of power, and hours of use for each energy source used for lighting, and for each electric device.

In the CEF project, data from the electric company showed average residential power consumption of 121 kWh/month and 408 kWh/month for commercial consumers.

For the CEF project, very few consumers were willing or able to provide their electric bills, so the enumerators relied on data provided by the type and use of lighting and appliances. Equation 4 illustrates how consumption was determined utilizing the basic data described above. For lighting, this included the sum of the multiplication of the watts of power of each energy source used for lighting by the daily hours of use (hours/day). The sum of all the energy sources used for lighting was multiplied by 30.4 days/ month and then divided by 1000 W/kW to obtain the kWh/month value consumed for lighting.

Equation 4. Calculation of power consumption for lighting

Lighting (kWh/month) = (((W1*H1) + (W2*H2) + …. + (Wn*Hn))*30.4)/1000

W1 = power in watts for lighting 1

H1 = hours per day used for lighting 1

30.4 = days/month (365 days/ 12 months)

1000 = conversion factor from watts to kW

On average, a rural household consumes 24 kWh/month for lighting. By multiplying 24 kWh/month by the lighting conversion factor of 5 klmh/kWh, results in a consumption of 120 klmh/month.

For household electrical appliances, each appliance was assigned a standard number of watts. For example, 80 watts were assigned to fans and 200 watts to standard television sets. These standard reference numbers were then multiplied by the hours of use for each appliance that the consumer indicated during their interview. The study assumed that refrigerators were plugged in all the time and assigned a standard consumption of 100kWh/month. For the CEF project, average household consumption of electricity for appliances was 109 kWh/month, and thus the total average residential power consumption amounted to133kWh/month.

Price of Alternative Energy Sources (Pa)

As shown in Table 1 above, for the CEF project the average expense for alternative energy sources for lighting was US$ 6.81/month. The same chart also indicated that the total klmh/month was 8.89. With these two data points, we were able to determine the cost per lighting unit simply by dividing US$6.81 by 8.89 klmh, and arriving at US$0.77/klmh.

The CEF project was exceptional because the potential beneficiaries of the project had

To express the economic benefit in terms of the scope of the project analysis, the net present value (NPV) of the benefit is calculated.

Table 1. Average expenditures for alternative energy sources (lighting only)

Energy Source	US$/month	Klmh/month	US$/klmh
Small candles	2.31	1.91	1.21
Medium-sized candles	2.22	1.91	1.16
Big candles	0.08	0.33	0.24
Small oil lamp	0.27	0.26	1.03
Medium-sized oil lamp	0.37	0.52	0.70
Big oil lamp	0.29	0.40	0.72
Kerosene lamp, tube	0.49	1.84	0.27
Kerosene lamp, wick	0.15	0.37	0.40
Kerosene lamp, pressure	0.01	0.30	0.04
Turpentine lamp, tube	0.32	0.99	0.32
Turpentine lamp, wick	0.01	0.02	0.47
Big batteries	0.21	0.02	8.61
Medium-sized batteries	0.07	0.01	5.80
AA batteries	0.02	0	16.00
Total	**6.81**	**8.89**	***0.77**

* Note: The last number is not a total. It is calculated by dividing 6.81 US$/month into 8.89 Klmh/month.

already benefited from an electric service, albeit with frequent and prolonged blackouts. The expenditures cited in the preceding paragraph were for alternative energy sources used during these blackouts. The lack of reliable electric service resulted in consumer consumption of both alternative energy sources (Pa), which means that actual consumer WtP and overall consumption of energy would have to include both Pe and Pa.

Let us assume a scenario in which an electric service provides an average of 18 hours/day of electricity. We further assume that for the remaining 6 hours without electricity, consumers use alternative energy sources, and the electricity outage is proportional over a 24-hour period. Then 18 kWh/month of electricity is obtained for lighting. Multiply the 18 kWh/month by 5klmh/kWh, resulting in 90 klmh/month of benefits. Add this figure to the 8.89 klmh of alternative energy to get 98.9 klmh/month. Distributing the fixed electricity rate to a lower amount of kWh makes the average cost increase to US$ 0.14/kWh, which multiplied by the 18 kWh results in US$2.53. The surveyed population thus would obtain a total of 98.9 klmh/month at a cost of US$9.34, resulting in a value price (Pa) of US$0.094/klmh.

Quantity of Alternative Energy Sources (Qa)

As described above, the Qa for the CEF project was 98.9 klmh/month.

The data shown in Table 2 were inserted into Equation 1 to calculate an estimated economic benefit for an average residential customer of US$7.34/month. The NPV calculation assumes a time period of 20 years and an 8% interest rate. Therefore, the NPV of this benefit is approximately US$865 per consumer.

To estimate the economic benefit of the energy consumed for operating electric appliances, one must subtract the electricity consumption used for lighting from the total consumption. The average consumption, calculated from the CEF project survey, was 133kWh/month. This estimated what

Table 2. Summary of variables needed to calculate the economic benefit for lighting (CEF project)

Variable	Description	Unit	Value
Pe	Price of electricity	US$/klmh	0.027
Pa	Price of Alternative Energy Sources	US$/klmh	0.094
Qe	Quantity of electricity	Klmh/month	120
Qa	Quantity of Alternative Energy Sources	Klmh/month	98.9

the consumer would use if they had electricity 24 hours a day. With electricity service for only 18 hours/day there was an estimated unsatisfied demand of 25kWh/month, of which 6 kWh was for lighting and 19 additional kWh for other uses. Multiplying 19 kWh/month by US$0.140/kWh results in US$2.66/month; added to the economic benefit for lighting of US$7.34, that renders a total of US$10.00/month and a NPV, at 20 years and an 8% interest rate, of approximately US$1,179.

For the Tomoyo project, energy consumption data recorded for the community of Potolo indicated an average residential consumption of 18.5 kWh/month for lighting, at a cost of approximately 15 Bolivianos per month. The total cost per unit was US$0.10/kWh. In non-electrified households, consumption of candles, fuel for wick lamps, and other alternative energy sources equated to approximately 1.25kWh/month, for which the average residential consumer paid almost 19 Bolivianos/month. The expenditure per unit was thus US$1.91/kWh. Therefore, the unit cost for lighting in communities without electricity in Potolo was almost 20 times greater than the cost of electricity. The economic benefit for lighting was estimated at US$17.88/month.

The disparity between the amount and cost of klmh for electricity and alternative energy sources was clearly dramatic, and resulted in a substantial economic benefit for the non-electrified consumers of Tomoyo.

As a corollary, Table 4 presents the formula and calculation for the consumer economic benefit for non-lighting uses of energy.

Table 3. Formula and calculation of consumer economic benefit for lighting (Tomoyo project)

Lighting only - Surplus To Consumer*: D = Qa*(Pa-Pe)+((Pa-Pe)/2)*(Qe-Qa)			
Whereas:			
Pe	Price of Electricity	US$/klmh	0.021
Pa	Price of Traditional Energy Sources	US$/klmh	0.38
Qe	Consumption of Electricity for Lighting	klmh/month	92.72
Qa	Consumption of Traditional Energy Sources for Lighting	klmh/month	6.26

Qa klmn/month	(Pa-Pe) US$/klmh	(Pa-Pe)/2 US$/klmh	(Qe-Qa) klmn/month	Economic Benefit - Lighting US$/month
6.26	0.36	0.18	86.46	17.88

*Source: World Bank Report No. 255/02, "Rural Electrification & Development in the Philippines: Measuring the Social & Economic Benefits"

Table 4. Formula and calculation of consumer economic benefit for other uses of energy (Tomoyo project)

Other Uses of Energy - Surplus to the Consumer*: D=Qa*(Pa-Pe)+((Pa-Pe)/2*(Qe-Qa)			
Whereas:			
Pe	Price of Electricity	US$/kWh	0.10
Pa	Price of Traditional Energy Sources for Other Uses	US$/kWh	1.42
Qe	Consumption of Electricity for Other Uses	kWh/month	16.8
Qa	Consumption of Traditional Source of Energy for Other Uses	kWh/month	0.64

Qa kWh/month	(Pa-Pe) US$/kWh	(Pa-Pe)/2 US$/kWh	(Qe-Qa) kWh/month	Economic Benefit for Other Uses US$/month
0.64	1.32	0.66	16.12	11.48

*Source: World Bank Report No. 255/02, "Rural Electrification & Development in the Philippines: Measuring the Social & Economic Benefits"

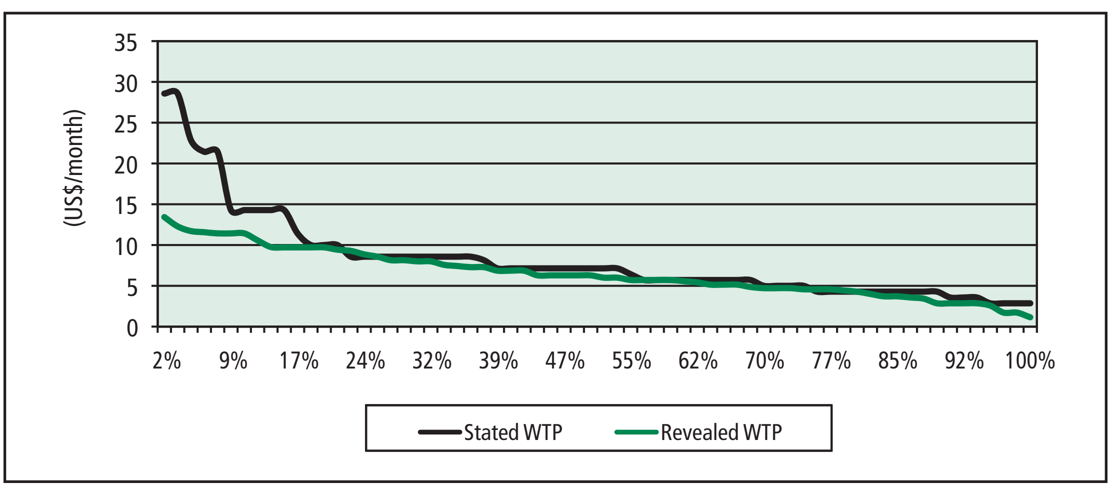
Presenting the Final Results

With all of the analyses of consumer WtP and economic benefit complete, the results should be presented to the reader in a clear and concise manner. The presentation of analytical results should include graphics, charts, and/or figures, with accompanying text that provides interpretation and support. The final results should include the Expressed and Revealed WtP for alternative energy sources and electricity, consumption of electricity, and the economic benefit for the individual consumer as well as for the project. The results obtained from the theory, methodology, and analysis described in this module become not only an end to this process but also important inputs for the technical and financial analysis of the project.

The results of the Expressed and Revealed WtP for electric service can be presented in many different ways. The following charts present some concrete examples.

Figure 6 illustrates the comparison between the Expressed and Revealed WtP for a community surveyed in Haiti. There was no existing electric infrastructure in the community and therefore

Figure 6. Expressed vs. Revealed WtP (Haiti project)



the results indicate only the Revealed WtP for alternative energy sources. The chart indicates that the majority of surveyed individuals spent more than US$5.00 per month for alternative energy sources. Their Expressed WtP reveals that they were willing to pay more for electric service than indicated by their current Revealed WtP.

The results from surveys conducted in the Dominican Republic offer a perspective on a different reality. In this case, the majority of interviewees had access to electricity, but due to frequent and prolonged blackouts, they had to spend additional money on alternative energy sources. Therefore, their Revealed WtP adds together their expenditures for alternative energy sources and for electricity from the national grid.

Figure 7 shows the Revealed and Expressed WtP for the CEF project in the Dominican Republic. Note that the Revealed WtP curve intersects with the US$20/month line at the point representing 20% of the population. This means that 20% of the population spends more than US$ 20/month and the remaining 80% of the population spends less than US$20/month on energy sources.

Obviously, there exists a large gap between the results illustrated for the Dominican Republic and Haiti, not only in their respective levels of consumption, but also in their Expressed WtP. In the Dominican Republic, the interviewees indicated that they were not willing to pay more than what they were presently paying for energy. However, in Haiti respondents said they would be willing to pay more for electric service than their Revealed WtP indicated.

Another way of showing Revealed WtP is in the form of a table or chart. Table 5 demonstrates the Revealed WtP of energy consumers in the Dominican Republic. At one extreme, 7.1% of the population spends US$2.50/month or less

Figure 7. Expressed vs. Revealed WtP, (CEF project)

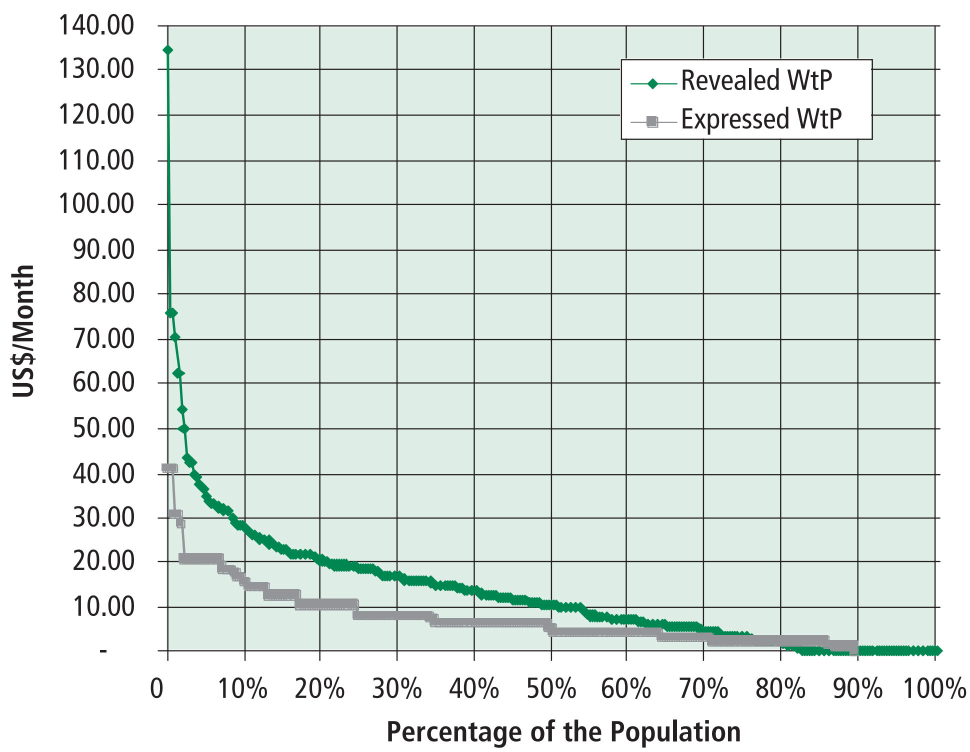


Table 5. Revealed WtP in the electric sector

Revealed WtP (US$/month)	Percentage	Accumulated Percentage
1 < = 2.50	7.10%	7.10%
2 > 2.50 < = 5.00	11.10%	18.20%
3 > 5.00 < = 7.50	14.00%	32.20%
4 > 7.50 < = 10.00	13.00%	45.20%
5 > 10.00 < = 15.00	15.40%	60.60%
6 > 15.00 < = 20.00	10.30%	70.90%
7 > 20.00 < = 50.00	17.70%	88.50%
8 > 50.00 < = 100.00	6.00%	94.50%
9 > 100	5.50%	100.00%
Total	**100.00%**	**100.00%**

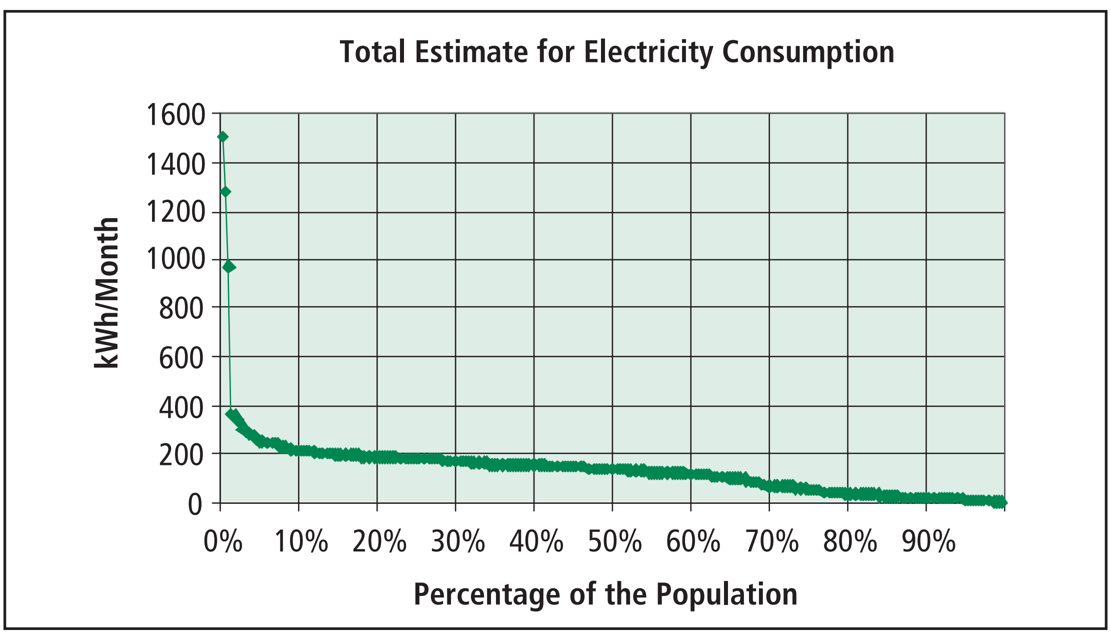
on energy, while 5.5% spend more than US$100/month. The reader can see that in the accumulated percentage column, almost 71% of the residential population spends US$20 or less per month.

Figure 8 illustrates residential and commercial electricity consumption in the CEF project area in the form of a demand curve.

In the figure below, 35% of the population consumes less than 100kWh/month while roughly 15% of the population consumes more than 200kWh/month. Between these two points, there exists a flat section of the curve (extending from approximately 15% up to 65% of the population) equating to 50% of the population consuming between 100 to 200kWh/month.

For such purposes as tariff studies or subsidy considerations, it is important to view the WtP results in terms of unit costs. Table 6 indicates consumer WtP in US$/kWh for residential

Figure 8. Demand curve for electricity



consumers in the Dominican Republic. The exhibit demonstrates that the unit price of electricity is more expensive for the consumers on both extremes of the consumption curve. Those who consume the least (who in turn are the poorest) and those who consume the most (the majority of which have their own portable generator) are the ones who pay the most per kWh. For example, from the residential population, consumers of less than 50kWh/month paid an average of US$0.30/kWh, while those who consumed more than 1,000 kWh/month paid US$0.32/kWh.

The next to last column of Table 6 shows the monthly expenses for energy sources (Revealed WtP) as a percentage of the general monthly expenses included in the fourth column. The last column shows the expenses for electricity as a percentage of monthly expenses. The survey asked certain questions related to monthly expenses, such as expenses for food, housing, health, education, etc. The sum of all these expenses was used as an estimated indicator of family income. This amount appears in the fourth column of Table 6.

Results of economic benefit analysis are normally shown using charts, but they can also be presented as bar graphs that illustrate the difference between energy costs and value of the alternative energy sources and electricity.

Using the WtP Results in Technical and Financial Analysis

The feasibility analysis of an electrification project requires understanding the relationship among the economic, financial, and engineering analyses, as well as the contribution of each analysis in determining the feasibility and design of the project.

The analyst requires multiple parameters from different sources for a complete analysis. Table 7 shows a summary and examples of parameters used in a feasibility analysis of an electrification project and the source of each parameter.

Along with the parameters in the chart, the information intake includes vital demographic information, such as the number of families that live in the target region of the project. The engineering analysis must also have information available concerning the location of the houses and the energy source. Tools such as GPS data, satellite images, and aerial photographs are useful in this process, along with physically counting the number of houses in the community.

Growth rates for consumer demand projections and project load forecasts can be procured from a variety of sources, as illustrated in Table 8.

Table 6. Revealed WtP (Dominican Republic, residential consumers)

Consumption Range (kWh/month)	Percentage of the Residential Population	Average Revealed WtP (US$/kWh)	General Monthly Expenses (US$/month)	Monthly Revealed WtP as % of Monthly Expenses	Electric Bill as % of Monthly Expenses
1 < = 50	6%	0.30	144	6%	2%
2 > 50 < = 100	5%	0.19	175	7%	3%
3 > 100 < = 200	43%	0.15	243	10%	6%
4 > 200 < = 300	18%	0.16	416	9%	5%
5 > 300 < = 700	17%	0.21	731	13%	7%
6 > 700	11%	0.32	1,768	30%	19%
Total	**100.00%**				

Table 7. Summary of analysis parameters

Parameter	Value	Source
Coverage (initial)	70%	WtP Study
Coverage (from 5 up to 20 years)	90%	Past data from the electric company that will operate the project, and experience of the team
Average residential consumption (kWh/month)	130	WtP Study Past data
Average commercial consumption (kWh/month)	250	WtP Study Past data
Write-offs (%)	6%	Past data from the electric company that will operate the project, and experience of the team
Collection Index (%)	90%	Past data from the electric company that will operate the project, and experience of the team
Scope of analysis (years)	20	Set by the analysis team
Interest (%)	8%	Financial conditions in the country
Discount rate (%)	12%	Discount rate used in the country
Cost of purchased energy (US$/kWh)	0.07	Prevalent prices in energy purchasing contracts
Income Tax (%)	25%	Laws in effect
Municipal Tax (%)	3%	Laws in effect

Contribution to the Financial Analysis

The data and analysis on consumer WtP represent essential input for project financial analysis, as they influence the determination for a cost of service tariff, project penetration rate, and the number of consumers that are estimated to be connected by the project, from implementation onward for a defined time period (often 20 years). Combining the average consumption in kWh/month, the number of users, and the consumer WtP allows the project manager to run models of analysis for different scenarios and in this way, determine the final tariff rate.

Contribution to the Engineering Analysis

Project engineering analysis requires knowing the estimated number of consumers to be connected to the system, the estimated amount of electricity that will be consumed, and the geographic location of the consumers. The WtP study and economic benefit calculation can contribute to these three variables depending on how responsibilities are assigned and what data already exists.

With reference to the number of users, the first thing to know is the total number of houses in the region of the project. There are several

Table 8. Summary of growth rates

	Annual Growth Rate (%)	Source
Population	1	National census adjusted to the target region
Number of Residential Users	3	Past data from the electric company
Number of Productive Uses	4	Past data from the electric company
Consumption of Public Lighting	1	concerning growth rate of the population
Residential Consumption	3.6	Past data from the electric company
Productive Use Consumption	5	Past data from the electric company

ways to obtain this information. In some cases, recent census data is available and reliable. In many cases, however, either no census has been conducted recently or the results are not reliable. Data can also be obtained from satellite images or aerial photographs. These images and photos must have a resolution that allows for the counting of each house. If it is not possible to obtain "number of houses" data by other means, then field workers must physically count the houses in the community. This becomes more feasible when the community is small and in a relatively compact region. Since it is important not to duplicate efforts, coordinate such counting with other project teams, such as the engineering team.

After counting the total number of houses in the region, determine the percentage of the population that will connect to the project. The results from the WtP study will help define the percentage of coverage and/or the penetration rate. Using the WtP study and an estimate for consumption in kWh/month, along with the rate scenarios, the analyst can create and evaluate a corresponding model for the analysis.

Average consumption of electricity can usually be determined from the willingness-to-pay data of communities without access to electricity. The amount of electricity that the beneficiaries could acquire, at different rates, derives from the amount of money spent monthly on alternative energy sources.

Geographic location is another important aspect in the design of the electric system. Preferably a team of trained technicians conducts a geographic study. In some cases, the WtP survey team can take a GPS device with them to obtain some preliminary geographic information, such as the locations of existing substations, electrical poles, large transformer banks, etc.

Contribution to Determining Subsidy

Analysts use the economic benefit results to determine the maximum subsidy that should be provided to the project. If the cost of investment per consumer required to execute the project is greater than the economic benefit, then the investment is not justified. To obtain this information, calculate the NPV of the economic benefit for the term of the analysis (often 20 to 30 years).

For the Tomoyo project in the Department of Potosí, Bolivia, the total economic benefit to the consumer was US$29.36/month or approximately US$352 per year. Considering a term of twenty years, the NPV of the economic benefit is approximately US$3,000 per consumer. An investment cost of US$500,000 was assumed based on estimated material and equipment costs to connect 600 consumers. The cost per consumer was US$833. Therefore, the project is justified because the NPV of the economic benefit is greater than the investment cost. This project could be subsidized at 100% of the capital cost of the project and still present a net economic benefit for the country.

For the CEF project in the Dominican Republic, the total economic benefit was US$10 per month. The NPV was approximately US$1,179. The engineering analysis and the financial analysis estimated a total of 16,000 consumers (even though this number could grow up to 17,000 or more in the future). The cost of the CEF project was estimated at approximately US$7 million, which, when divided by 16,000 consumers, results in a cost of US$438 per consumer. This project is also justified because the NPV of the economic benefit is greater than the investment cost. As with the Tomoyo Project, 100% of the capital cost of the CEF project could be subsidized and still present a net economic benefit for the country.

Analysts use the economic benefit results to determine the maximum subsidy that should be provided to the project. If the cost of investment per consumer required to execute the project is greater than the economic benefit, then the investment is not justified.

Distribution Line Design and Cost Estimation for Rural Electrification Projects

MODULE 7 OF NRECA'S TECHNICAL ASSISTANCE GUIDES

7

EXECUTIVE SUMMARY

This module sets forth the principles and establishes the recommendations for the electrical design of a rural electrification project or system. It also describes the procedure for the determination of costs, which serve as the basis for the feasibility analysis.

An electrical configuration design greatly influences the cost of the project to be developed and the quality of the service for the final user. An optimal design ensures the supply of service under adequate technical conditions and at minimum cost. Cost estimation on the basis of an optimal system ensures that the feasibility study uses the appropriate figures and that the lines, if constructed, have the required technical capacity to supply energy to final users.

This module broadens the information and procedure described in Module 5: *Methodology for Evaluating Feasibility of Rural Electrification Projects*, and provides further information for Module 8: *Financial Analysis of Rural Electrification Projects*. Likewise, the costs presented in this module assume the use of economical line structures and an optimal mechanical design, such as developed in the *Simplified Staking Manual for Overhead Distribution Lines*.[1]

The norms, parameters, and design criteria used in this module derive from the rules established by the RUS of the United States which have also been adapted to rural electric systems in several countries. Their fundamental characteristics are the following:

- The three-phase system is configured with four wires, including three phases and a multi-grounded physical neutral.
- Single-phase primary lines consisting of a phase and neutral are the main mechanism for rural distribution.
- Application of single-phase transformers sized from 5-25kVA, with use of transformers over 25kVA only for specific cases in three-phase banks.
- Limits on the length of low voltage networks to reduce technical losses, improve service quality, and reduce possibilities for illegal connections.
- Universal metering.

This system of design represents an integrated philosophy for development of rural electrification projects. It presents a basis for design and provides the professional user with the necessary tools for its application.

The proposed procedure for project design consists of the following series of steps.

1. Compilation and documentation of technical information on the existing system serving the project area.
2. Surveys in the field on the quantity and characteristics of consumers and preparation of georeferenced information on the geographic layout and concentration of users' housing in relation to the existing system. To obtain geographic information, the design system

An optimal design ensures the supply of service under adequate technical conditions and at minimum cost.

[1]Southern Engineering Company, *Simplified Staking Manual for Overhead Distribution Lines* (Washington, D.C.: The Association, 1992).

recommends use of modern instruments based on satellite positioning or GPS, instead of older techniques based on approximate measurements by means of vehicle odometers or distance estimations.

3. The operating electric company develops a study of the economic selection of conductors, to establish standard conductor sizes for use in multiple rural projects.

4. Design of the project at hand, using a power flow model with suitable characteristics, so as to accurately simulate system performance.

5. Consideration of coordination of protection against overcurrents and as an integral part of project design.

6. Estimation of project costs.

7. Presentation of the project in a sufficiently well-grounded and documented manner, so as to ensure that the technical aspects previously enumerated have received due consideration.

An optimal design ensures provision of service with standardized levels of service quality at minimum cost.

This module presents and develops the necessary methods, and adds application examples, to enable readers to put into practice the integrated system design approach.

INTRODUCTION

This module presents the steps to follow for the electrical design and cost estimation of a rural electric distribution project, to be used as input to the feasibility study.

The definition of the electric configuration is of vital importance for the future project because it has a fundamental influence on its cost and on the quality of the service for the final user. An optimal design ensures provision of service with standardized levels of service quality at minimum cost. The estimation of costs on the basis of an optimal system thus ensures that the feasibility study uses the appropriate figures and that the lines, if constructed, have the necessary capacity to supply the users with the service quality required, at the lowest economically achievable level of technical losses, at least during the period of project analysis.

This module does not discuss the mechanical design of the lines to be constructed. Mechanical design should be done only after determining and defining the feasibility of a project and after confirming its execution with the interested parties, whether they are the financial entities or the beneficiaries. An appropriate mechanical design ensures that lines work reliably and safely and that they do not cost more than necessary. For the mechanical design of electric lines see *Simplified Staking Manual for Overhead Distribution Lines*,[2] upon which the designs used to develop the reference costs in this module are based.

BACKGROUND AND JUSTIFICATION

The design fundamentals presented in this module derive from the rules established by the RUS. These approaches have been adapted to rural electric systems in several countries, and their fundamental characteristics are:

- Configuration of the three-phase system with three-phase wires and a multi-grounded physical neutral. This configuration permits the application of overvoltage protection with protection levels lower than the phase-to-phase voltage of the system. This configuration in turn permits the use of basic insulation levels for equipment that is lower than the levels applied in three-phase systems either without neutral or with a neutral grounded only at the source. It also permits a significant reduction in the investment cost of transformers and other equipment.

[2] Ibid.

- Application of single-phase primary lines consisting of phase and neutral as a principal means of rural distribution. The use of single-phase lines, while providing adequate service for most uses and for the existing demand for electricity in the rural area. Three-phase lines are required to maintain system balance between phases in the system as well as to serve specific concentrated three-phase loads.

- Application of single-phase transformers. The application of single-phase 5-25 kVA transformers is preferred, leaving the modules of over 25kVA only for specific requirements such as three-phase banks. The use of a larger number of relatively small transformer modules, as compared with a smaller number of larger transformers used in an urban system, improves the quality of service for scattered users, reduces the investment in low-voltage systems and reduces system losses, even though the transformers themselves may cost more.

- Limit the length of low-voltage networks. This limited length reduces technical losses, improves service quality, and reduces the possibility of illegal connections.

- Application of universal metering. An individual meter should be installed for each customer, to ensure measuring of each customer's own electric energy consumption. The universal metering rule applies to public consumers, schools, and municipal buildings as well as to private consumers.

This design methodology for a rural electrification project represents an integrated philosophy, and it should be applied as a whole. Its presents a basis for design and provides the professional user with the necessary tools for its application.

PROJECT DESIGN

The process of electrical design for rural electrification projects consists of four steps:

- Compilation of available information on the area to be electrified. The electric company or jurisdictional institution in charge of supplying the electric service in the adjoining area should provide the initial information, especially if the project is connected with this entity and this entity will operate the service once the project is executed. This information is necessary, but not sufficient to characterize the area, for reasons to be explained shortly.

- Analysis of the area to be electrified. This means determining the location of consumer concentrations, based on the actual conditions of the project area. During this process the information gathered from the electric service operator in the adjoining area should be confirmed, to the extent possible.

- Analysis of the loads and configuration of the proposed system. This step determines the loads represented by the concentrations of potential users and designs the system configuration to supply them, including route design, the features of primary lines, and the location of transformer points.

- Analysis of the proposed system, to confirm that it fulfills requirements for service quality, particularly with respect to the delivered voltage levels. This step enables planners to determine whether it is necessary to improve the existing system to permit the extension of the new system to be constructed.

What follows are the details of the process of analysis development and the use of the necessary tools, and an example how the process applies to a real project. The project used as an example is an electrification project in the Tomoyo region, near the city of Sucre in Bolivia.

The Tomoyo project provides for the supply of electric service to approximately 1,000 new consumers, scattered among 11 communities. The project includes the construction of approximately

Application of single-phase primary lines consisting of phase and neutral as a principal means of rural distribution.

30 km of 14.4kV single-phase lines, up to an end point 77 km from the supply substation. This project poses a challenge in maintaining adequate service voltage and in achieving the coordination of system protection.

Compilation of Information from the Electric Operator

It is very important to start the electric design of a project with information from the company that will undertake the role of operator upon completion of the work, to obtain all existing data available on the project area and to take into account the rules of the company that is to maintain and operate the lines.

The project engineer should start the electric design from the standards established by the electric company, as long as they comply with the technical criteria included in this module.

When the project designer visits the office of the operating company, he or she should gather the following information:

Standards and Materials Used

Every distribution company has preferences as to the use of materials and line hardware. Some companies use wooden poles while others use concrete or metal or a mix of all. Normally, electric companies have standardized structures, often based on RUS standards. It is also usual to have standardized conductor sizes for a company's distribution systems. Therefore, the project engineer should start the electric design from the standards established by the electric company, as long as they comply with the technical criteria included in this module.

Plans for Network Extensions in the Project Area

The electric company may have plans to extend its lines to the area contemplated in the project, and they might even have a final design for the extension project. Many times these plans are compiled by local governments, such as the prefecture or the municipality,and can be highly politically motivated. The designs prepared under these conditions usually have many serious flaws and cannot be applied directly.

The electrical design may have been based on social pressure (such as the decision to install three-phase lines, though the demand does not justify this configuration), or the mechanical design failed to consider the criteria of the mechanical design guide. Even so, these plans may contain useful information for elaborating a final design according to the procedures of this module. Such useful information generally includes the identification of communities in the project area and the number of potential users. It is always necessary, however, to validate the data received, as these often prove to be biased, to confirm the distance between towns and communities, and to verify the technical information on the existing system to which the project is to be connected.

Options or Alternatives for Extension of the Electric System to the Project Area

The electric company may have or know about an expansion plan for the present system, which would affect the project being considered. Examples of possible expansion plans are the construction of new sub-transmission lines, substations and/or generating plants. Such information would have great value for planning the new project. Take expansion plans into account with caution, however, because most distribution companies' expansion plans for rural areas are either overly general, without financing, or based on out-of-date information about major configurations for transmission systems. Although taking into account the plans of other companies may prevent unnecessary expenditures in the development of a project, it is important not to condition the design on the existence of other projects that may not be executed in time.

When associated projects have received the necessary approval from financing sources and other approvals such as those related to environmental impact, it is valid to consider those projects in the planning of a rural electrification project.

Point of Origin or Supply for the Project

During the visit of the project designer to the office of the electric company, obtain all available information on the source or supply point for the new project. Whether or not the electric company has all the necessary information, it is also necessary to pay a visit to the project site to verify the data. The data to be obtained from the electric company are the following.

Voltage Level of the Existing Distribution Lines

Existing voltage levels may be of the 15kV, 25kV, or 35kV class, each of which comprises a number of options. For example, the 15kVvoltage class includes 11kV, 12.47kV, 13.2kV, and 13.8kV. The 25kV level includes 20kV, 22kV, and 24.9kV, etc. The 35kV level includes voltages like 33kV and 34.5kV. An electric company must have more than one voltage level in its system, e.g., 12.5kV and 34.5kV. Then, even if a line is currently energized at a lower voltage, for example at 12.5kV, the company may be willing to consider a conversion to 34.5kV, if this is technically justifiable. In Bolivia, the system voltage used by distribution companies is in the process of being standardized at 35kV, 25kV, and 15kV. Few companies there are still maintaining systems in other voltages.

Number of Phases Available

It is important to know how many phases are available in the project sector: one, two or three phases. If three phases are not available at the initial point (usually at the end of the existing line), one must find out how far the three-phase line goes, so as to take it into account if conversion to a three-phase line is necessary.

Physical Neutral

Some rural area distributors have adopted systems without a physical neutral. The system used for single-phase configurations without a physical neutral, is referred to as Single Wire Earth Return (SWER), must still comply with and respect various design criteria. If no physical neutral exists at the initial point, it is necessary to determine where the neutral of the existing system ends, so as to take into account the costs of adding the neutral.

Distance from Substation

If the electric company has updated and sufficiently detailed maps, one can determine with their help the distance from the substation to the initial point of the project. This information is necessary to model the voltage drop in the existing line, as well as to simulate the power flow and the voltage drop in the proposed project.

Existing Conductor Size from Substation to the Project

To carry out a power flow analysis, one needs to know the cross-section of the existing conductor in the line from the substation up to the initial point of the project to be studied. The cross-section of the neutral conductor (if it exists) must be determined, as well as the cross-section of phase conductors. If there are conductors of more than one cross-section in the line between the substation and the initial point, record each cross-section of the conductor in the corresponding stretch, as well as its respective length.

Load in the Existing Line

The load in the existing line is another critical component in defining the conductor cross-section and/or number of phases of the system that will be analyzed in the power flow study in order to determine the voltage drop in the existing line. If there are important loads, record their location so as to be able to model their effect in the power flow study. If the existing line has to be divided into segments, for the reasons indicated in the previous section, be sure to divide the existing load among the same segments.

Average Energy Consumption in the Last Electrified Community

In rural electrification projects it is possible to estimate energy consumption in the communities to be electrified examining the energy consumption in the nearby communities that already have electric service. Quite probably the electric company will have information on the energy consumption of existing users in these nearby communities. If the electric company furnishes financial data only, such as the monthly amount collected, the kWh consumption can be calculated using the company's current tariff structure.

Existing Penetration Rate in the Electrified Area

To size the new project, it is necessary to know how many users out of a total of potential users will be connected to the project in the first year, and the period over which the rest are likely to begin service. The penetration rate is the proportion of potential consumers who receive service in any particular year, expressed as a percentage of total potential users. One can project a penetration rate for the area of the proposed project by knowing the penetration rate in nearby areas that have already been electrified.

Substation Characteristics

Another piece of important information for the electrical model of the system concerns the characteristics of the substation. The following characteristics must be obtained from the electric company:

Source Impedance

Conducting a fault current or short-circuit study so as to specify the overcurrent protection scheme requires obtaining the impedance on the high-voltage side of the substation. Many times, the electric distribution company will have to request this information from the company in charge of transmission. The data may come directly as impedances of positive and zero sequence, but very often it is shown as magnitude of the fault current for a three-phase fault and a single-phase fault. In that case, calculate the impedances according to Equations 1 and 2.

Equation 1: $Z1 = \dfrac{Vf}{I3f}$

Equation 2: $Z0 = \dfrac{3xVf}{I1f} - (2xZ1)$

Where:

Z1 = positive sequence impedance [ohms]

Z0 = zero sequence impedance [ohms]

Vf = nominal phase to ground [volts]

$I3f$ = magnitude of three-phase fault current [amperes]

$I1f$ = magnitude of single-phase to ground fault current [amperes]

The reference voltage should be of the same voltage level as the fault current. That is, if fault currents are obtained at the 69kV busbar of a substation, the Vf value that should be used to derive the fault impedances in ohms is 39.837 volts. If the engineer does not have the data on the phase angles of the faults, average values are –72º for Z1 and –75º for Z0.

Capacity of the Substation

Information must be compiled on the kVA capacity of power transformers at the substation. If there is more than one transformer, compile data on all of them and record whether they are connected in a bank, in parallel, in series, or independently (serving separate low voltage buses).

Available Capacity at the Substation

After recording the capacity of each transformer at the substation, one must record the maximum demand of each transformer to be able to calculate the capacity available for the proposed project. If there is a lack of capacity in the substation transformers, either an increase of capacity would have to be budgeted at the existing substation or a new substation installed closer to the project area.

Voltages on Both Sides of the Transformer

In every transformer at the substation, record the rated (nameplate) voltage for both the high voltage winding and the low volage winding. In many instances the nominal voltages of transformers are not the same as the nominal voltages of the system and the difference may influence the results of power flows.

Available Taps in the Transformer

Always record the presence of voltage adjusting taps on both sides of the transformer, as they influence the transformation relationship and therefore the output voltage of the transformer. There are usually five taps of +/- 5% on the high voltage side, i.e. +5%, +2.5%, 0% (nominal), -2.5% and –5%, but this varies according to the manufacturer and the purchase specification of the transformer. Also determine the position of the tap switch and therefore the tap position on which the transformer is operating.

Existence of Automatic Voltage Regulation

Another important factor to model in the power flow is the presence or absence of devices for voltage regulation. If the substation has voltage regulation equipment, verify whether it is incorporated into the transformer or separated, along with whether it is automatic or manually operated.

Impedance of the Transformer and Ground Connection

One of the most important pieces of information in the substation electrical model is the impedance of transformers and the way in which the neutral, if any is grounded. This information is usually presented on transformer name plates as %Z at the self cooled or OA rating. In the case of an autotransformer or a three-winding transformer, record three impedances: primary secondary, primary tertiary, and secondary tertiary. In some substations, where it is necessary to limit the magnitude of the fault current to ground, an impedance may be installed in the ground connection. If such an impedance exists, record its value, so as to include it in the power flow model. If the relation X/R of the transformer impedance is not specified, adopt the relation 10:1.

Transformer Connections

All three-phase transformers, or single-phase transformers connected in three-phase banks, can be defined by the connection configuration of delta or star windings, both on the high voltage side and on the low voltage side. Record the configuration of the connection on both sides of the transformer. This configuration does not influence the power flow model, but it does influence the fault current model, which is normally calculated using the same model of the electric system. The calculation of these fault currents influences the determination of the protection system that the project will need so as to be reliable.

Characteristics of Overcurrent Protection Devices

At every substation there should be overcurrent protective devices (such as fuses, reclosers, breakers, etc.) both on the high voltage side and low voltage side. For each device, record these characteristics:

- the type of device,
- the brand,
- the pickup current,
- relay settings (if any)
- the current transformer taps (if any)

Always record the presence of voltage adjusting taps on both sides of the transformer, as they influence the transformation relationship and therefore the output voltage of the transformer.

This information must be recorded for two reasons. First, it ensures that all devices are properly coordinated . Second, it ensures that with the loads of the new project, the load currents in the feeder do not exceed the pickup current of the protective device.

Characteristics of Other Substation Equipment

There may be other equipment in the substation that could have a great influence on the power flow model, such as capacitors and reactors, so be sure to record their capacity and form of connection to the system.

There may be other equipment in the substation that could have a great influence on the power flow model, such as capacitors and reactors, so be sure to record their capacity and form of connection to the system. For capacitors, record the control mode, whether it is automatic or manual. For automatic capacitors, also record the operation criteria (voltage, phase current, power factor, or time of day).

Field Inspection

After compiling the available information at the office of the electric operator, it is necessary to confirm and complement that information by visiting the project area to establish the geographic relationship between the loads to be electrified. During this visit, the basic configuration of the system to be installed will take shape, subject to modification during the process of analysis. For this reason, during this visit, one needs some way to establish distances and locations of towns and probable loads. The traditional way to perform this task is to get the best map available of the area and measure the distance between key points using the odometer in the vehicle. Although this procedure meets the needs of the project, modern technology affords a more accurate and advantageous option through use of GPS satellites for establishing geographic references. A GPS unit is portable and low cost, with geographic accuracy of +/- 7 meters in autonomous operation. Additional technologies offer the capacity for greater accuracy, but for this kind of project design they are not necessary.

Apart from their ability to accurately locate key points, most GPS units allow for the recording of a "track," which serves as a basis to construct a power flow model. Given the availability of these instruments at low cost and their advantages in laying out a plan for rural systems, there is no reason to resort to old techniques. This module therefore assumes the use of a GPS device during the field visit. The field visit thus includes the following steps:

Georeference of All Sites with GPS

During the visit to the site, the engineer should use the GPS to obtain georeferenced data for the routes followed (and/or the probable route for electrical lines to be installed) and of all the points of interest, such as the substation, the end of the three-phase line, the initial point of the project and the center of each community to be considered in the project.

Tracks or Routes

All along the route, the GPS can mark out and record the route followed. The engineer must make certain that the GPS is in the right mode to mark and record the route, because upon returning to the office, this information will be very useful in determining the length of both the existing lines and those to be installed.

Waypoints

The GPS capacity can also mark the location of points of interest for the project, such as the location of the substation, the end point of the three-phase line, the initial point and the center of each community to be considered in the project. Each such point should be recorded with an indicative name, which could be the complete name of the community (according to the GPS capacity) or a simpler indicative name. In any case, keep a written file of all waypoints with the indicative name, the real name of the community, and the additional characteristics of each point.

Files vs. Active Memory

During the registration of points and routes, the active memory of the instrument fills up. The engineer must ensure that the memory does not become full, because the GPS then erases the older data or simply stops recording new data. In either case, data are lost. Depending on the model, the active memory may fill in half a day or one whole day. When the memory is full, the engineer must download the data to the computer, so as to make room in the memory. If the GPS model permits it, the instrument operator should transfer the data of the active memory to a GPS internal file, so as to empty the active memory later, without losing data. Most GPS models have room in their memory for at least eight files of route data, besides their active memory.

Record Distances and Consumers

While using the GPS to record the route followed and the points of interest, keep a record of distances between all points, as well as the accumulated distance so far, to facilitate the calculation of distances later. This record gives the engineer the distances between communities or other points of interest without having to measure them again. Record the number of users in each community in the same record.

Table 1 provides an example of a record of points of interest, associated with distances.

Figure 1 shows the file on routes and points that was recorded in the GPS for the Tomoyo project.

Substation

Although all the necessary data can be obtained in the office of the electric company, it is often necessary to visit the substation and verify personally all the data on the equipment name plates. If the engineer can obtain permission for such a visit, it enables the collection of data that are often not archived in the office, such as the voltage taps in the transformers.

Verify Key Data

If visiting the substation, the engineer must verify all data compiled in the office and obtain all the missing data. The following table list shows the minimum data to be obtained:

- Capacity of the transformer
- Maximum load in the transformer
- Nominal high voltage rating
- Nominal low voltage rating
- Existence of tap changer in the transformer
- Present position of the tap, if any
- Winding configuration of the transformer (delta-wye, autotransformer, etc.)
- Type of voltage regulation
- Impedance of the transformer
- Overcurrent protection and settings
- Other equipment?

Draw a Single Line Diagram of the Substation

To more easily remember the configuration of the substation, the engineer must draw a single lilne diagram of the substation, showing the connections of all the equipment in the substation. Figure 2 is a practical example.

Between Substation and Initial Point

After obtaining the data on the substation and its georeferenced location, survey the existing line between the substation and the initial point of the project. Along the way he must record the route track with the GPS and mark the points of interest, such as the center of the communities already electrified, the significant existing loads, the end of the three-phase line, and the initial point of the project (if it is not the same). All along the way, keep a record as previously described.

Initial Point of the Project

At the initial point, verify the data on the existing line, such as the available voltage level (15kV, 25kV, or 35kv), number of phases available (1, 2, or 3), existence of a physical neutral, and the cross-section of the existing conductor. Also verify the characteristics of the existing users in the last electrified community, such as the following:

Consumption of Energy in the Last Electrified Community

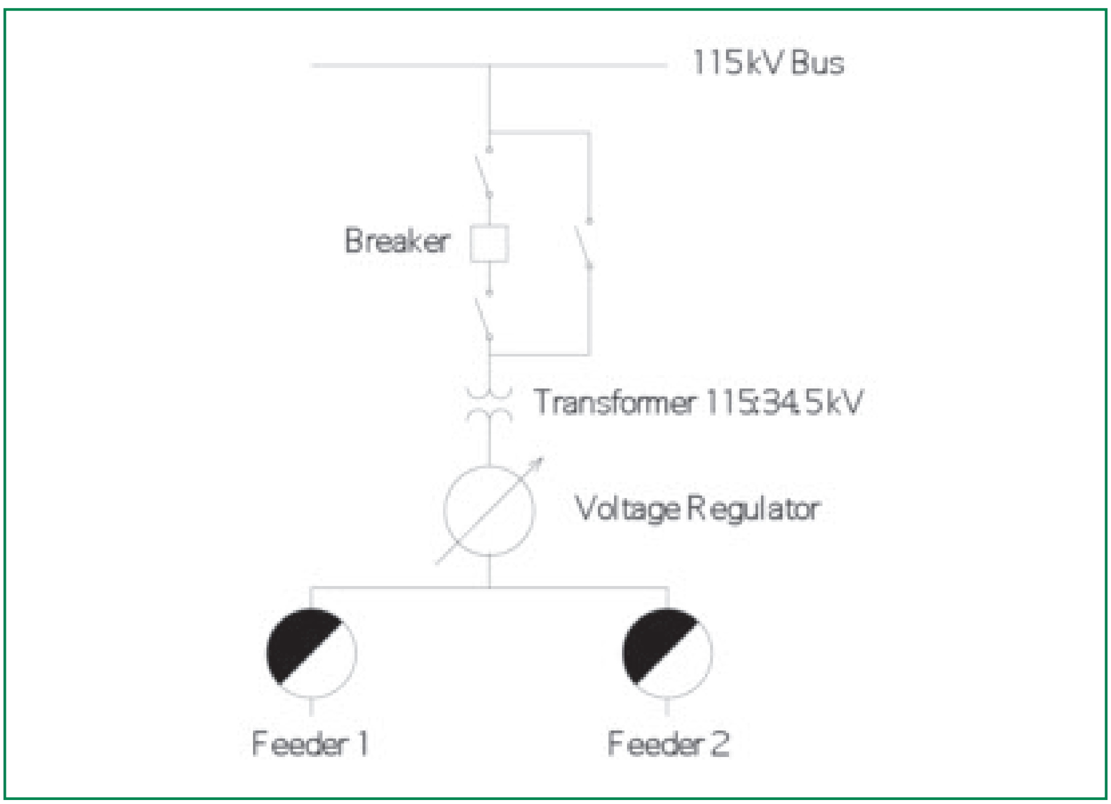
Quite probably, the communities that will benefit from the project have the same patterns of electric energy consumption as the neighboring communities that already have an electric energy supply. Therefore it is worth conducting a quick investigation on this aspect in the electrified community nearest to the initial point. The engineer must ask several community members about their present electricity consumption, especially at schools

Table 1. Record of km and users per community (Tomoyo)

Point of interest/community	km	Number of users	Notes
Substation Aranjuez	0	–	
Industrial Park	6	(3500kW)	(existing load)
Airport	8	(100kW)	(existing load)
Santa Catalina	13.3	(50kW)	End of three-phase line
Gra Loma	18.5	8	
Tawricasa	22.6	15	
Punilla	24.3	41	
Silvico	27.8	5	
Chataquila	30.6	1	Convent
Chaunaca	36.6	10	
Caraviri	41.4	30	
Colpacucho	48.9	30	
Potolo	54.3	300	End of line
Molle Molle	59.7	38	Chuquisaca
Molle Molle 2	60	102	Potosí
Sorojchi	62.6	73	
Isluco	64.6	22	
Yoroca	65.1	69	
Tomoyo	68.5	84	
Joroba	69.3	41	
Llatapata	70.6	35	
Kasapata	72.5	35	
Sorocoto	76.2	108	
Soroscopa	77.2	41	

Figure 1. Sample graphic of GPS points and routes data (Tomoyo)

Figure 2. Sample single line diagram



(if any), shops (if any) and in some houses. The average consumption obtained may be applied to potential users in the communities of the proposed project.

Present Penetration Rate in the Electrified Area

In the electrified community that is nearest to the initial point, perform a quick evaluation of the penetration rate. Check how many houses there are in the town, and how many have been connected to the electric system, and in what time spanthey have been connected. With this sample it is possible to define the penetration rate to be applied to the communities contemplated in the new project.

The project designer must survey the whole project, visit all the communities and georeference the roads as well as the central point of communities.

Survey the Proposed Project and Georeference with GPS

The project designer must survey the whole project, visit all the communities and georeference the roads as well as the central point of the communities (the square, the church, the school, etc.). Along the way, the engineer must spot and note down the features of the land that the electric lines will have to cross (many curves, gorges or streams, rocky ground, etc.). This provides an idea of the construction difficulties and helps with estimating the costs adequately. During the survey, the project designer must keep a record of the distances between communities and of the number of potential users in each community, as shown in Table 1.

Survey of Potential Users in each Community by Category

During the visit to each community, estimate the potential users in each category of consumption. Visit some of the most important loads to get an idea of the probable demand on the electric system.

One may base the estimation of the electricity demand on small generators or diesel engines that are installed and working and the energy consumption according to the liters of fuel the motor needs (daily, weekly or monthly). Typical consumers and categories found in rural areas include the following:

- Residential
- Shop
- Workshop
- Church
- School
- Sanitary post
- Water system
- Lumberyard
- Hotel
- Industries
- Three-phase loads

Table 2 shows an example of categorized users and loads for the Tomoyo project.

Evaluation of Loads

After the visit to the project area, the engineer should process all the data compiled. The first step of data processing is the calculation of the demand in each community. The best way to calculate the demand is to import all data in an Excel worksheet. Include the data illustrated in Table 2, which identifies the number of users per community, consumer category, and monthly consumption per category. From those data one can calculate the energy consumption for the entire community. The demand of each community can then be estimated, using the methodology explained in the following section.

Table 2. Count of users by class for the Tomoyo project

Community	Residence	Shop	School	Mill	Medical Center	Phone kiosk	Total
kWh/month	**25**	**75**	**100**	**250**	**150**	**120**	
Molle Molle (Chuquisaca)	54	1	1	1	–	–	57
Molle Molle (Potosi)	146	2	1	1	1	1	152
Sorojchi	105	2	1	–	1	1	110
Yoroca	98	3	1	1	–	–	103
Tomoyo	114	4	1	3	1	1	124
Llajtapata	50	1	–	–	1	–	52
Isluco	30	1	1	–	–	–	32
Jirota	60	1	1	–	–	–	62
Kasapata	50	1	–	–	1	–	52
Sorocoto	160	2	1	–	1	–	164
Soroscopa	60	1	1	–	–	–	62
TOTAL	**927**	**19**	**9**	**6**	**6**	**3**	**970**

Calculation of Total Energy Consumption per Community

The next step is to calculate the total energy consumption per community, by multiplying the number of potential users in each category by the specific consumption of that category, as included in the demographic study described in Module 5: *Methodology for Evaluating Feasibility of Rural Electrification Projects.* Table 3, column 3 shows the results of this step, taking as an example the data of the Tomoyo project, as recorded in Table 2.

Estimation of the Demand According to the REA Formula

The recommended methodology to calculate the demand of communities of predominantly residential consumer groups, described in Equation 3, is based on extensive studies of the characteristics of electric consumption in relation to the demand. It takes into account the number of consumers and the average monthly consumption, in kWh/consumer. The method defines the consumer factor (Factor A) and the kWh factor (Factor B), where Factor A reflects the fact that diversity increases with increases in the number of consumers, and Factor B reflects the improvement in the load factor with the increase in specific consumption.

Table 3. Demand and Consumption of Energy per community (Tomoyo)

Community	Users	kWh	kW
Molle Molle (Chuquisaca)	57	1,775	8
Molle Molle (Potosí)	152	4,420	19
Sorojchi	110	3,145	14
Yoroca	103	3,025	13
Tomoyo	124	4,270	18
Llajtapata	52	1,475	7
Isluco	32	925	5
Jirota	62	1,675	8
Kasapata	52	1,475	7
Sorocoto	164	4,400	19
Soroscopa	62	1,675	8
TOTAL	**970**	**28,260**	**124**

Equation 3: Demand (D) = (Factor "A") *(Factor "B")

Where:

Factor A = C*(1-0.4*C+0.4*(C^2+40)^0.5)

Factor B = 0.005925*(kWh/month/consumer)^0.885

C = number of consumers

Sometimes there is isolated power generation in some of the communities to be included in the project.

This method is empirical in the sense that its derivation was based on statistical correlation of measurements of loads in kW for consumer groups with different levels of specific consumption. The method has been verified for its use in countries with limited residential penetration of air conditioning.

In Bolivia, for example, a program of measuring and correlation indicated that the equation projects the demand of a mixed residential/commercial group, with an error margin not over 5%. This is a very good correlation indicating that the method is reliable. Table 3 shows an application of this method to calculate the demand of the communities in the Tomoyo project.

Estimation of the Demand Using Data from Existing Generation

Sometimes there is isolated power generation in some of the communities to be included in the project. In such cases, gathering generation data to estimate current demand may help to make more realistic projections. In that case, visit the power plant or system administrator to obtain the actual data available. Sometimes no direct data on loading are available due to a lack of instrucmentation or failure to record the information. However, fuel consumption data are almost always available. Use the next two points to understand how to calculate demand and energy using these data.

kWh per Liter of Fuel

The key information for calculating the energy consumed by the community is the record of fuel consumption (diesel or others), in liters or gallons per day or month. In many cases, particularly in countries where the government subsidizes the price of fuel, there are thefts and clandestine sales of the subsidized fuel, so that the engineer must try to determine how much fuel is actually used for electricity generation. With this information, the project designer can estimate the electrical energy generation, using the following conversion factor: 10 kWh/gallon or 2.64 kWh/liter diesel

Generator Size

Another point to consider is the capacity or size of the generator in HP, kW, or kVA. This does not directly indicate the real demand of a town, because generators are usually oversized, but it does indicate the maximum possible demand of a community supplied by this generator. One way to evaluate whether or not the generator is oversized is to calculate the energy generated as described in the section titled "Calculation of Total Energy Consumption per Community" and then calculate the demand using the methodology indicated in "Estimation of the Demand According to the REA Formula." Then compare the results.

Line Length

After projecting the energy consumption and calculating the demand per community, create a table recording the length of primary line required between each community and the next. This information may be compiled from the data record obtained during the visit to the site, as explained previosly. Also, the information will be necessary to estimate the costs of the project. Table 4 shows a sample filled-in calculation sheet.

Analysis of Electric System Behavior

With all the information available about communities, including distances between them and energy demand, the engineer should base the electric design of the system on an analysis of power flows or voltage drops, to ensure that the project can supply the anticipated maximum demand under acceptable service conditions.

In addition to determing the voltage behavior of the project, the power flow study permits an evaluation of losses and allows the engineer to examine the required number of phases, the eventual need to reinforce the existing supply systems, or the requirement to establish a distribution system with a different voltage level from the existing one in the area.

Criteria for Analysis

To determine whether the study has met its objective, it is necessary to establish criteria for the evaluation and acceptance of results. The criteria normally used in planning studies relate to the level of voltage, the capacity of equipment and lines, the reliability of the service, and the level of losses.

Voltage Level

Minimum voltage levels are normalized in most countries, with the measuring point for purposes of application of regulations at the interconnection node between the supply system and the client, i.e. at the client's energy meter. Usually, the regulations set a range of acceptable voltage, both above and below a nominal value. Sometimes two ranges are included, one for normal conditions and another for contingencies.

In Bolivia, for example, the acceptable range is +4%/-7.5% for normal conditions and +7%/-10% for emergencies. Where there are regulations on the voltage level, apply the regulated acceptable values for normal conditions for planning purposes, leaving the additional margin for emergency conditions during the operation of the system. If there are no rules in a given country, use the values +5%/-10% for planning purposes.

It is important to point out that the limit values for voltage level have been set at low voltage at the point of delivery to the client, i.e. at the meter. For planning studies it is not customary to perform the analyses down to this level, but rather at a system level. Planning studies that use the methods presented in this module are based on the voltage at primary level, i.e., before the voltage drop represented by the distribution transformer, the low voltage (secondary) lines, and the service drop. As reference criteria, use the following values:

The engineer should base the electric design of the system on an analysis of power flows or voltage drops.

Table 4. Demand calculated per community (Tomoyo)

Community	Users	kWh	kW	Km
Molle Molle (Chuquisaca)	57	1,775	8	6.4
Molle Molle (Potosi)	152	4,420	19	–
Sorojchi	110	3,145	14	2.7
Yoroca	103	3,025	13	2.5
Tomoyo	124	4,270	18	4.2
Llajtapata	52	1,475	7	2
Isluco	32	925	5	2
Jirota	62	1,675	8	1
Kasapata	52	1,475	7	3
Sorocoto	164	4,400	19	3.5
Soroscopa	62	1,675	8	1
TOTAL	**970**	**28,260**	**124**	**28.3**

- Voltage drop in transformer 2%
- Voltage drop in secondary network 2%
- Voltage drop in service drop 1%
- Total drop in LT 5%

Taking into account an acceptable range of +5%/-10% for the service voltage, these values imply that the range to be applied to the study of the voltage drop in the primary system will be +/-5%. These values correspond to the RUS system design, which comprises single-phase transformers, whose impedance is limited by standards to 2.5%, along with very short lengths of low voltage lines.

Minimum voltage levels are normalized in most countries, with the measuring point for purposes of application of regulations at the interconnection node between the supply system and the client, i.e. at the client's energy meter.

Capacity of Equipment

For an acceptable power flow study of loading in the first year of the project, maximum demand must be limited to no more than 50% of the nominal capacity of the equipment and conductors. This criterion leaves a margin for growth without establishing an excessive level of overcapacity. Where the project involves an additional load on a line or existing substation, the criteria may be modified so as to maintain a margin of global capacity in the line or existing substation of 50% of the project load in the first year. In the last year of the analysis, the loads projected on any line or equipment should be within their normal capacity, i.e. allowing 100% demand in relation to the capacity.

Service Reliability

Service reliability, i.e. the frequency and duration of interruptions, depends more on maintenance of the system during operations than on the decisions made during the design, with one exception. This exception is the provision for a coordinated protection system against faults. A coordinated system ensures that for phase-to-phase faults, as well as for phase-to-ground faults, there are protection elements sensitive enough to detect and clear the fault. The system should be sectionalized in a planned manner, not only to help identify the location of the fault, but also to limit the number of affected consumers.

Since the most common type of fault in electric systems is the phase to ground fault, with an incidence of nearly 85% of all faults, it is important that reliable mechanisms be defined to detect and clear this type of fault. Ground faults often involve contact between one phase and some not very conductive element, like a tree or dry soil, so this is not an easy task. The criteria used by the RUS design system to identify and clear ground faults allows for a nominal resistance of 40 ohms in a series with the fault, which represents the resistance of the tree or soil contacted. This resistance is normally in series with the line impedances between the source and the fault, tending to reduce the minimum fault current. The coordination of elements that clear the fault is then designed to respond to this reduced fault current. The system used to clear faults may consist simply of fuses or a combination of reclosers and fuses, as long ast the rule of fault resistance is respected.

The minimum level of fault current for coordination purposes is a function of the nominal voltage of the system. Taking into account the specified resistance of 40 ohms and the impedance of only 5 km of line, the minimum fault current would be:

- For systems of 12.5kV phase to phase – 165 amp.
- For systems of 24.9kV phase to phase – 330 amp.
- For systems of 34.5kV phase to phase – 460 amp.

By applying the normal rules of uses the recloser/ fuse coordination system, one can derive the maximum load allowable for the circuit and branches to ensure a coordinated system. By applying a similar reasoning to various voltage levels and considering the features of commercially available fuses and reclosers, the following results may be obtained:

- For systems of 12.5kV between phases:
  - Maximum load, main circuit – 70 amp
  - Maximum load, branches with fuses – 25 amp
- For systems of 24.9kV between phases:
  - Maximum load, main circuit – 140 amp
  - Maximum load, branches with fuses – 65 amp
- For systems of 34.5kV between phases:
  - Maximum load, main circuit – 200 amp
  - Maximum load, branches with fuses – 80 amp

These limitations are substantial when dealing with circuit loads, especially for systems of 12.5kV. While some devices for the electronic control of reclosers allow this range to be extended, protection coordination should be an element in the integral design of the system.

Control of Technical Losses

The control of technical losses has many aspects to be weighed, and not all of which are part of the system design process. An example of an extraneous factor is limitation of losses in the distribution transformers. When purchasing distribution transformers and evaluating their cost, one must use a formula that determines a financial value for losses, both for no load losses and load losses. This procedure applieds during the process of purchasing the equipment, not at the system design level.

However, the selection of the conductor cross-section is within reach of the system designer. This selection process optimizes investment expenses and guarantees more efficiency in the distribution of energy, considering both the cost of construction and the cost of technical losses resulting from the energy flow through the line. The process consists of applying Equation 4 for several levels of loads and of line construction costs with several alternative cross-sections of conductors.

Equation 4: $C_A = K_A$*(Const) + K_L*(Loss)

Where:

C_A = Total annual cost of one kilometer line

K_A = Fixed charge rate for investment costs, typically = 0.15

Const = Construction cost of one kilometer line with a specific conductor cross-section

K_L = Acquisition cost of one kWh energy at the beginning of the project

Loss = Annual loss in kWh of one kilometer line with the specific conductor cross-section for a specific peak demand and load factor.

$= (LLF)(n)(I^2R)*8.76$

Where:

LLF = Load factor of losses = $(\text{Load factor})^2$ *0.84+ (Load factor) *0.16

n = 3.0 if the line is three-phase, 2.0 if the line is single-phase

I = Phase current in amps for the specific load

R = resistance in ohms of one kilometer of the specific conductor

The repetitive application of this equation for different conductors and levels of demand results in a matrix of annual costs that determines the range of loads for which each conductor is optimal, thus identifying the conductor with the minimum annual cost.

This effort seems cumbersome, but its best application is to conduct a generalized study over the entire electric company system. The aim would be to select a group of no more than four cross-sections for conductors, which could reasonably cover among them the range of anticipated loads. This limits the inventory of connectors and other accessories without losing the capacity to meet the requirements of the system.

The aim would be to select a group of no more than four cross-sections for conductors, which could reasonably cover among them the range of anticipated loads.

After selecting the group of optimal conductors, repeat the analysis only when there is a substantial change in one of the factors, such as a significant increment in the cost of energy or a change in line design that seriously affects construction costs.

As an example of this procedure, Table 5 shows the result of a comparative analysis of annual cost for three-phase lines of 24.9kV under the following conditions:

- Cost of energy: US$ 0.08/kWH
- Load factor: 40%
- Power factor: 90%

Table 5: Comparison of annual costs for three-phase lines of 24.9kV

Conductor	#4 ACSR	#2 ACSR	#1/0 ACSR	#2/0 ACSR	#4/0 ACSR	397.5 MCM
Cost of Construction US$/km	$8,961	$9,140	$10,766	$12,941	$15,073	$24,314
Load kW	**Total Annual Cost US$/km**					
400	$1,406	$1,410	$1,639	$1,961	$2,273	$3,654
600	$1,483	$1,458	$1,670	$1,985	$2,288	$3,662
800	$1,591	$1,526	$1,713	$2,019	$2,310	$3,673
1000	$1,730	$1,614	$1,767	$2,062	$2,337	$3,688
1200	$1,900	$1,720	$1,835	$2,115	$2,371	$3,706
1400	$2,101	$1,846	$1,914	$2,178	$2,411	$3,727
1600	$2,332	$1,992	$2,005	$2,251	$2,456	$3,752
1800	$2,594	$2,157	$2,109	$2,333	$2,508	$3,780
2000	$2,888	$2,341	$2,225	$2,425	$2,566	$3,811
2500	$3,756	$2,887	$2,568	$2,698	$2,738	$3,903
3000	$4,817	$3,553	$2,988	$3,031	$2,948	$4,015
3500	$6,071	$4,341	$3,484	$3,424	$3,196	$4,148
4000	$7,519	$5,251	$4,056	$3,878	$3,483	$4,301
4500	$9,159	$6,281	$4,704	$4,393	$3,807	$4,475
5000	$10,992	$7,433	$5,428	$4,968	$4,170	$4,669
5500	$13,018	$8,706	$6,229	$5,603	$4,571	$4,883
6000	$15,237	$10,100	$7,106	$6,300	$5,010	$5,118
6500	$17,648	$11,616	$8,060	$7,056	$5,487	$5,374
7000	$20,253	$13,252	$9,089	$7,873	$6,002	$5,649

- Annual fixed charge rate: 0.15
- Cost of line construction based on 2005 prices of materials

The gray values represent the minimum costs for the load indicated. A #4 ACSR conductor has an application range of only up to 400kW, so it should not be considered as a conductor for standard use. Instead, #2 ACSR has an application range from 600kW to 1,600kW, which enables it to serve as a standardized conductor. A #1/0 ACSR conductor has an application range of 1,800kW to 2,500kW, although its range of advantage over #2 is not too marked below 2,000kW. A #2/0 ACSR conductor has no preferred application range, while the #4/0 conductor is preferred from 3,000kW to 6,000kW. For loads over 6,500kW, the optimal conductor is 397.5 MCM. In this example, the company would then remain with four normalized conductors, each one with a substantial application range, as follows:

- For loads up to 1,600kW: #2 AWG ACSR
- For loads of 1,601kW up to 3000kW: 1/0 AWG ACSR
- For loads of 3001kW up to 6500kW: 4/0 AWG ACSR
- For loads of 6501kW and over: 397.5 MCM ACSR

Other criteria may affect the selection of a normalized conductor. For example, the RUS recommends 1/0 AWG ACSR as the minimum standardized conductor for lines of the 35kV class, such as 33kV or 34.5kV_{LL}. (RUS 1724E-200, page 9-5). Another factor to be considered for the choice of conductor is the influence of safety standards in mechanical design. For instance, in conductors for primary lines, all conductors smaller than #2 AWG ACSR may be eliminated from the analysis, according to rule 235.B.1.b of the National Electric Safety Code (NESC).[3] This rule, which requires more horizontal separation for conductors smaller than #2 AWG ACSR, has the effect of making the spans shorter in primary lines with conductors smaller than #2 AWG ACSR. As a result, its cost per kilometer is higher than the lines using #2 AWG ACSR or those of greater sections.

After determining the cross-section of the phase conductor, the engineer must determine the cross-section of the conductor in the neutral. If the line is single-phase, the neutral should be of the same cross-section as the phase conductor, because both conductors share the same current. For a three-phase line, consider the use of a conductor with a smaller cross-section for the neutral, because in a three-phase line with balanced loads, a reduced current flows through the neutral.

The RUS Bulletin #61-4 recommends that the neutral conductor should have at least 20% of the capacity of the phase conductor in three-phase lines with balanced loads, and that they have similar characteristics in their sagging. Considering all the above, Table 6 shows a table of conductors with a reduced cross-section for the neutral.

Considerations in Power Flow Studies

A power flow study can be conducted with the help of specialized software, with general-use

[3]American National Standards Institute, *National Electric Safety Code* (New York: Institute of Electrical and Electronics Engineers, 2002).

Table 6. Reduced cross-section of neutral conductors in three-phase lines

Phase Conductor	Neutral Conductor
#2 AWG ACSR	#2 AWG ACSR-minimum size
1/0 AWG ACSR	#2 AWG ACSR
2/0 AWG ACSR	#2 AWG ACSR
3/0 AWG ACSR	1/0 AWG ACSR
4/0 AWG ACSR	1/0 AWG ACSR

spreadsheet software, by hand calculations, or with tables. However, to obtain reliable data, power flows should be carried out with a specialized engineering software package. Among the features found in such a package are some important aspects of the model method.

Model by Constant Load Instead of Constant Current

If the line is single-phase, the neutral should be of the same cross-section as the phase conductor, because both conductors share the same current.

Power flow studies that use computerized spreadsheets and simplified equation systems for manual application assume a constant load current in a given node, determined by dividing the load on the node by the nominal voltage. This is an approximation. At the end of the line, the voltage often differs from the nominal; it is the voltage at the source, less the voltage drop. If the current is then multiplied by the voltage at the end of the line, the model of constant current has effectively reduced the load in kVA of the node, yielding significant error in the voltage drop.

The method that comes closer to reality calculates a solution to the power flow, assuming a current that varies inversely with respect to the voltage of the node, to keep the load in kVA at that node constant. This model requires an iterative solution, i.e. repetition of the calculation until the differences between one solution and the previous are minimal. An iterative solution is difficult to implement in power flows based on spreadsheets or manual equations, but it is very common in specialized analysis packages.

The error caused by the difference in the load model is not very significant for voltage solutions close to the nominal. However, it becomes important with substantial voltage drops, where the difference in the current applied to the system is greater.

In the Tomoyo example of power flow, with a line of 77 km, conductor of #2 AWG ACSR and 4 MW load and using the constant load model, one could find a voltage drop of 10.3% and 38 kW of losses. But, using the constant current model, there would be a voltage drop of 9.87% and 37 kW of losses. These data represent an error over 4% in a rather small system, making for a significant difference in the evaluation of the system. The rate of error substantially increases when increasing the size and load of the system. Therfore, the program for power flow calculation should take into account a model based on constant loads and not on constant currents.

Capacity to Calculate the Capacitive Charging Current of Overhead Lines

Another simplification used by tables of voltage drops and spreadsheets is ignoring the capacitive charging current of overhead lines. This is another source of error, especially for long lines with light loads, the most common in rural electrification projects. For example, taking the small system in Tomoyo, with the technical and load characteristics described before there are 73 kVAR of capacitive effect. If this is not taken into account in the calculation of voltages, there would be an error of nearly 1% in the voltage drop and more than 5% in the calculation of losses. The error increases for systems with less load. Thus, the program for power flow should take into account the capacitive charging current effect of overhead lines.

Capacity to Model Unbalanced Loads

The reality of rural electrification lines, especially those with long, single-phase branches, is that it is difficult to achieve a balance of currents. The negative effect of the imbalance makes voltage regulation more difficult. Thus, it is important that the analysis system take this effect into account. Most programs for simplified power flow calculation use methods and equations based on positive sequence only, i.e., they cannot take into account the imbalance between phases. Many programs developed for the analysis of transmission systems also use the positive sequence approximation, because transmission lines are always three-phase and therefore always balanced. But this is not the case in distribution systems, so that the capacity to model unbalanced loads is essential.

Coming back to the Tomoyo project, the feeder for this project has 83% single-phase lines from the substation. Therefore, trying to study this system with a power flow based on values of positive sequence would not give a reliable result. Thus the power flow program for a distribution system should always have the capacity to make calculations with unbalanced loads, either with symmetrical components (an approximation) or with matrices (preferably).

Capacity to Calculate Unbalanced Impedances

Apart from their inability to model unbalanced loads, analysis programs using positive sequence approximations have no capacity to model unbalanced impedances. It is possible, though not very common, for a three-phase line to have different conductors in the different phases. For instance, it might have been constructed originally as a single-phase line with a given conductor cross-section and then converted into a three-phase line with another conductor cross-section for the two new phases. A still more common case of unbalanced impedances is a bank of single-phase transformers in which impedances are very similar but seldom exactly alike. Thus the power flow program for a distribution system should always have the capacity to calculate unbalanced impedances, preferably by using matrices.

Considerations for the Power Flow Model for the Tomoyo Project

The power flow analyses for the Tomoyo project, used as an example for this module, were performed with the Windmil analysis package (Milsoft Utility Solutions, Texas, USA). This package has all the required technical features for a power flow program and has an additional function called "LandBase," which very usefully creates the model of the system by directly importing the tracks and waypoints from GPS units. Figure 3 shows the Windmil screen with the GPS data of the Tomoyo project imported by LandBase.

This graphic shows the points of interest, such as communities included in the project and the routes between them, along the line. In the lower corner of the screen, the scale of the drawing appears along with geographic coordinates of a selected point. Figure 4 shows the communities of the Tomoyo project superimposed on GPS data.

Selection of Primary Voltage Level

After creating the geographic model, it is necessary to determine the voltage to be used for the new extension. The choice of a voltage level for a given project depends to a large extent on the levels already used in the area. Selecting a primary voltage that differs from the standard used in the project area requires the installation of substation, and possibly transmission, equipment. This decision should be carefully examined prior to final design. With that said, a voltage level of the 25kV or 35kV class may be reasonably introduced in the following circumstances:

- If the existing voltage (whether 5kV or 15kV) cannot be extended to serve the new project, without investing in substations and sub-transmission lines
- If the system has to serve large specific loads, which are scattered over a wide area, such as an irrigation project, in which case a different voltage level from the existing one that serves residential loads in the same area may be acceptable
- If the client or group of clients to be served represents a pilot project for a more extensive development of similar projects in the area
- If a sub-transmission voltage within the same company exists that may be used for distribution (In those cases in which the electric company has historically utilized a 34.5kV or 22kV as a sub-transmission voltage, these lines may be converted to fit distribution applications at an attractive cost.)

In the Tomoyo project, none of these considerations applied, so the project was developed at 14.4 kV

The reality of rural electrification lines, especially those with long, single-phase branches, is that it is difficult to achieve a balance of currents.

Figure 3. Windmil screen with GPS data (Tomoyo)

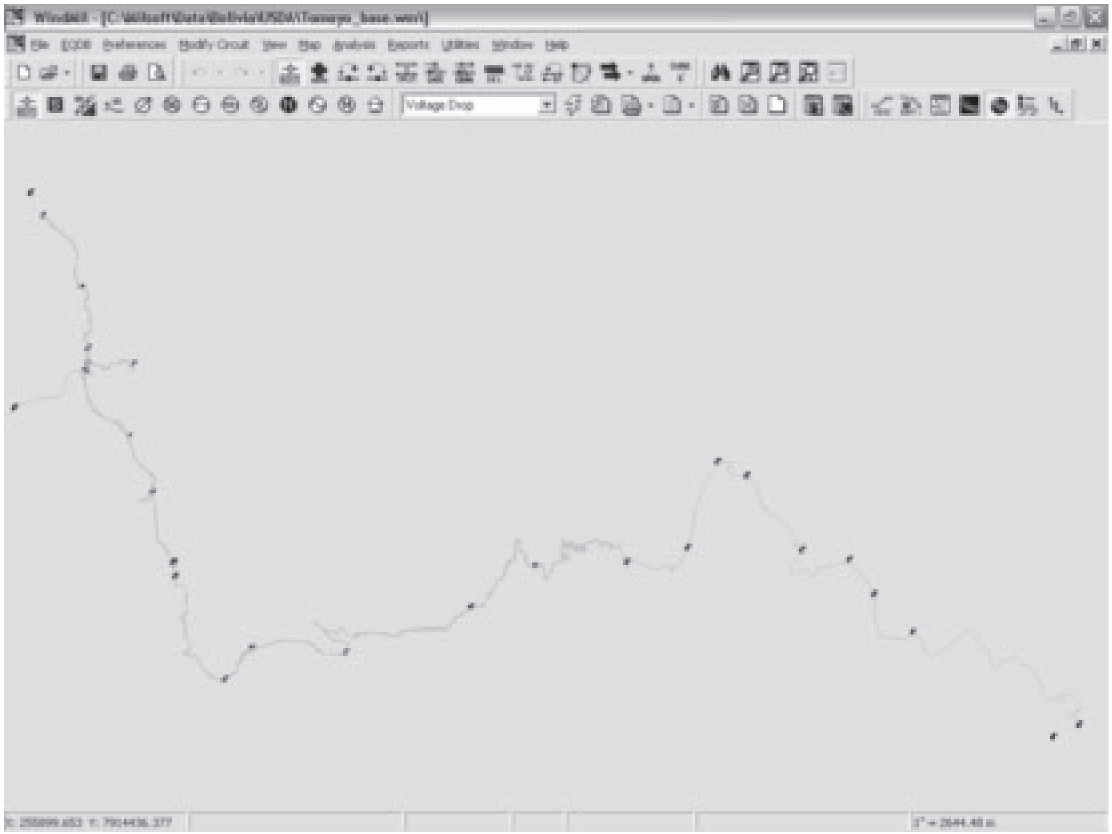
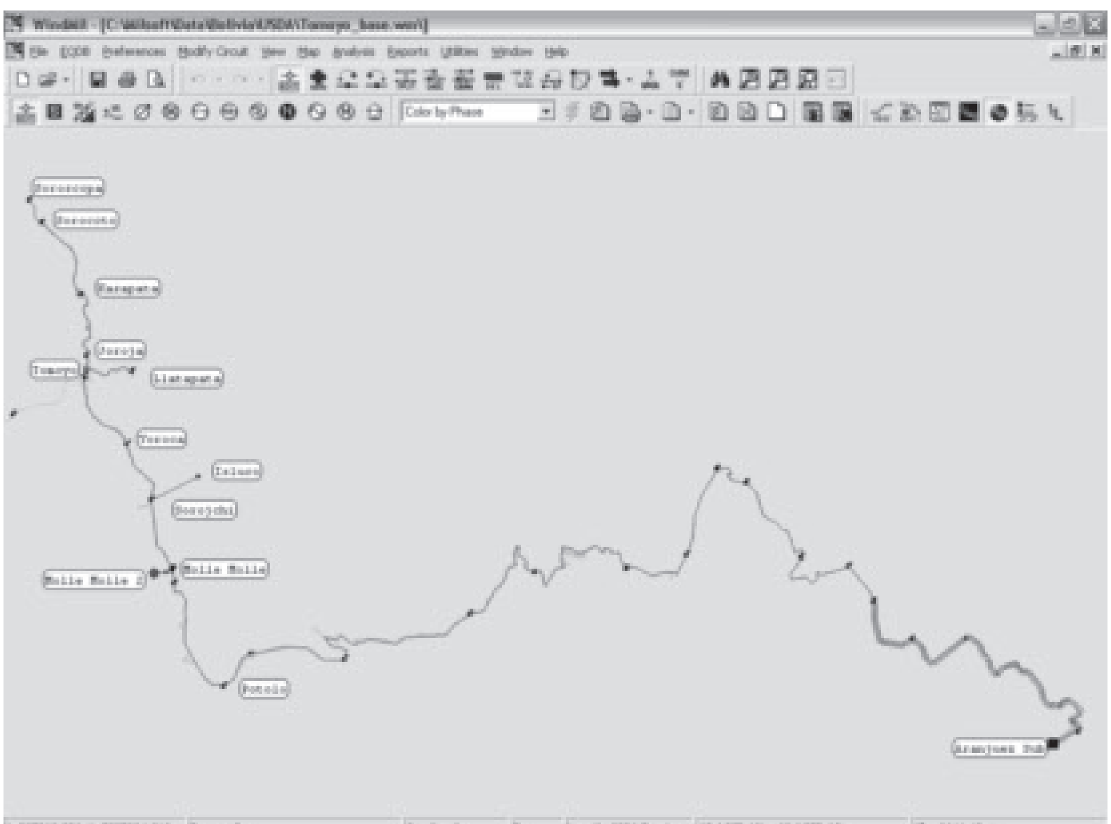


Figure 4. Windmil screen with GPS data and communities (Tomoyo)



(class 25kV) as an extension of the existing system.

Determination of the Number of Phases

After determining the length of the proposed system and calculating the demand of potential loads in existing lines and those proposed for the project, the engineer must determine the number of phases required in the proposed lines of the project. As indicated at the start, the RUS integrated design system assumes that rural lines should be single-phase, for economic reasons, i.e. phase and neutral. However, some situations require consideration of the extension of two-phase lines (two phases and neutral) or three-phase lines, for the following reasons:

- The current in one of the single-phase branches exceeds the limit established for a system of coordinated protection.
- The result of the power flow studies indicates that using a single-phase system for the projected loads will not maintain maintain voltage levels within regulatory limits.
- There are three-phase loads in the project area that are large enough to make a conversion into single-phase impossible. Generally, motors of over 10HP are three-phase, though the technology exists to overcome this limitation.
- The nature of the loads to be covered by the project rules out the use of single-phase systems. For example, a project to develop an extensive irrigation system with electric pumps of over 10HP each should be designed from the beginning with three-phase lines.
- There is a need to distribute the loads among phases to ensure a better balance of phase currents at the source. This is a necessary consideration in cases where the permissible percentage of current imbalance is regulated by law, as in Bolivia.

The need for alternative solutions to the extension of single-phase lines must always be justified on the basis of economic and/or regulatory considerations. Where the requirement for a three-phase service is only potential and not immediate, the design of the single-phase lines as standardized by RUS facilitates the conversion to a three-phase configuration, with the addition of a crossarm and two phase conductors. With the services of a properly trained contractor and with adequate equipment, it is possible to realize this conversion without de-energizing the single-phase line. For certain cases, it is possible to plan, initially, single-phase construction, to be converted to three-phase in the future, without losing the economic benefits of the initial single-phase solution.

The Tomoyo project did not require modification of the initial design, and the system was designed with single-phase lines.

Determine the Application of a Physical Neutral

In situations where loads are scattered, and with little growth potential, some companies and electric authorities have applied the SWER system, which consists of a single phase conductor without physical neutral. This system also can be found in areas where there are problems with the theft of the neutral conductor. The SWER system has been successfully applied in many countries, including Australia and Tunisia, among others.

In situations where loads are scattered, and with little growth potential, some companies and electric authorities have applied the SWER system.

The main considerations in its application are as follows:

- For situations with no anticipated hope of load growth beyond a very low initial level (8 amperes per circuit), it is possible to use steel conductors, long spans of around 250 meters, and a narrow right of way. This application achieves a 50% reduction in the construction cost of a conventional single-phase line with aluminum conductors steel reinforced (ACSR).

- When using conventional ACSR conductors to maintain capacity and facilitate service to higher loads or to permit the future conversion to three-phase systems, the economic benefits are lower. Savings would be around 12% due solely to eliminating the neutral conductor.

- MRT/SWER systems produce higher levels of interference with telephone circuits than a conventional single-phase line. This is not as much of a disadvantage as previously thought, given the trend toward the elimination of wired telephone systems.

- To control neutral-to-ground voltages in the service drops, implement a system of double grounding at the transformation points. A double grounding system uses a separate ground for the primary neutral of the transformer and another, at a certain distance, for the neutral of the low voltage system and the service drop. This arrangement slightly increases the cost for transformation points.

- To limit the voltage gradient to adequately ensure the safety of persons and pets, limit the maximum value of the resulting voltage in the grounding of the primary winding of the transformer, to 20 volts. To obtain this value for transformers of different capacities, one must ensure that ground resistances do not exceed the values indicated in Table 7. Particularly for the 7.2kV MRT/SWER system, achieving these values may increase the cost of grounding, especially in difficult types of soil.

- Another consideration is the separation between the primary system grounding and that of the low voltage system and service drop. The regulations used by the Australian Electrification Authority, which serve as the model for most SWER electrification efforts, require a 3 meter separation between the grounding of the primary winding of the transformer and the user's ground system, with that no interconnections between them. To obtain this separation, insulate the ground wire of the secondary neutral from the ground conductor of the primary neutral and install separate fields of ground rods.

Taking into account the advantages, disadvantages, and limitations of the MRT/SWER system, the decision for the Tomoyo project was to use a conventional single-phase system. i.e. with phase and physical neutral, so that the demand of the project would have 15 amperes for the year 20.

Determination of the Conductor Cross-section

The conductor cross-section should be determined according to the criteria set forth in the section on *Criteria for Analysis*, based on an economic choice and limited by considerations of protection coordination and voltage drops. For the conditions of energy costs, load factor, and power factor described in the same section, the economic matrix of conductors for 14.4kV single-phase lines appears in Table 8.

Again, the gray results represent the most economical conductors for the load indicated. The #4 conductor has an application range up to 200 kW, whereas the #2 conductor has an

Table 7. Maximum resistances for SWER ground systems

Voltage of the System	7.2kV	14.4kV	19.9kV
Module	Maximum Ground Resistance – Ohms		
10 kVA	15	30	30 (regulations)
15 kVA	10	20	27
25 kVA	5	10	16

application range of 250 kW to 550 kW, and the #1/0, from 600 kW to 900 kW. As previously, the #2/0 conductor has practically no application range and the #4/0 conductor is applicable only above 1000 kW. Taking into account that the limitation owing to the coordination of 14.4kV single-phase branches is 65 amp, or nearly 1000 kW, a #4/0 conductor cannot be considered for this application. Preferred conductors for 14.4kV single-phase lines are clearly the #2 ACSR for loads up to 550 kW and the #1/0 ACSR for loads from 600kW to the coordination limit of 1000kW. Since the load projected for the Tomoyo project is 124 kW for the first year, with a projection to be increased up to 250 kW until the year 15, the standardized, utilized conductor for this project is the #2 ACSR.

Minimum Voltage Calculation

After selecting the number of phases and cross-section of the conductor, run the power flow model to determine whether the selections made are adequate, or whether they have to be adjusted by increasing the number of phases and/or the conductor cross-section. Decisions should be based on the following criteria.

Voltage in the First Year

Upon running the program with the projected load for the first year, the result should show voltage levels of +5%/-5% with respect to the nominal voltage. The loads applied come from the analysis of the demand, which takes into account a certain

If values under 95% of the nominal voltage are found at any point in the model, increase either the number of phases or the conductor cross-section, according to the parameters specified in previous sections.

Table 8: Comparison of total annual cost for 14.4 kV single-phase lines

Conductor	#4 ACSR	#2 ACSR	#1/0 ACSR	#2/0 ACSR	#4/0 ACSR
Cost of Construction US$/km	$5,668	$6,015	$7,138	$8,163	$9,839
Load kW	Total Annual US$/km				
100	$873	$917	$1,080	$1,232	$1,480
150	$902	$935	$1,091	$1,241	$1,486
200	$943	$960	$1,107	$1,253	$1,494
250	$995	$993	$1,128	$1,270	$1,504
300	$1,059	$1,033	$1,153	$1,290	$1,517
350	$1,134	$1,080	$1,183	$1,313	$1,532
400	$1,221	$1,135	$1,217	$1,341	$1,549
450	$1,319	$1,197	$1,256	$1,371	$1,569
500	$1,429	$1,266	$1,300	$1,406	$1,590
550	$1,551	$1,342	$1,348	$1,444	$1,614
600	$1,684	$1,426	$1,400	$1,486	$1,641
650	$1,828	$1,517	$1,457	$1,531	$1,669
700	$1,985	$1,615	$1,519	$1,580	$1,700
750	$2,152	$1,720	$1,586	$1,633	$1,734
800	$2,332	$1,833	$1,656	$1,689	$1,769
850	$2,523	$1,953	$1,732	$1,749	$1,807
900	$2,725	$2,081	$1,812	$1,813	$1,847
950	$2,940	$2,215	$1,897	$1,880	$1,889
1000	$3,165	$2,357	$1,986	$1,951	$1,934

penetration rate for potential users. If values under 95% of the nominal voltage are found at any point in the model, increase either the number of phases or the conductor cross-section, according to the parameters specified in previous sections. Do not apply any voltage regulators in the first years. Figure 5 shows the result for the first year of the Tomoyo project analysis.

Voltage in the Final Year

Upon running the power flow program with the projected demand for the last (usually the 20th) year considered in the analysis of the project, the result should show that 90% of the nominal voltage is the worst situation. The loads to be applied come from the analysis of demand, which takes into account a certain penetration rate for potential users and the vegetative growth rate. From the year 2 on, the use of regulators is acceptable to maintain 95% of nominal voltage for final users, so as to comply with the profile of regulated voltage during the useful life of the line (usually 30 years). If a level below 90% of nominal voltage is observed at any node of the model, increase either the number of phases or the conductor cross-section in the first year, according to the parameters specified in previous sections. Figure 6 shows the result for the year 20 of the analysis, in the Tomoyo project.

Coordination of Protection for Overcurrents

With the same database as for the power flow, the engineer will be able to calculate the magnitudes of the fault currents, in order to conduct the coordination study on protection devices for overcurrents. Figure 7 shows the values of fault currents calculated for the Tomoyo project.

After calculating the fault currents, coordinate the protection devices. For this purpose, start the coordination process with the fuse devices of the distribution transformers. These fuses must be coordinated with the fuses of the laterals, then with the main line and finally with the recloser in the substation. A detailed explanation of the coordination procedure for the various protection devices is outside the scope of this module.

ESTIMATION OF PROJECT COSTS

After following the procedure detailed in the *Project Design* section, the project engineer has an electrical pre-design that includes the determination of line lengths, the number of potential users, primary voltage, number of phases, conductor size, and whether or not a physical neutral will be used. With these data, it is possible to prepare a detailed estimate of project costs. The following presentation lays out the procedure for estimating the cost of rural electrification projects.

Materials Database

The first step in estimating project costs consists in maintaining a database of the cost of materials, according to purchases or previous quotations. This database should include the unit price of each item of material, including the cost of shipment, and the total amounts for each purchase. Unit prices always depend on the volume of purchased materials, with greater volumes usually resulting in lower unit prices. This database must also differentiate between materials for projects of 15, 25 or 35kV,

Table 9. Format for a materials database

Description of Item	Historical Unit Price	Taxes	Inflation	Projected Unit Price

Figure 5. Sample three-line diagram of the power flow at year 1 (Tomoyo)

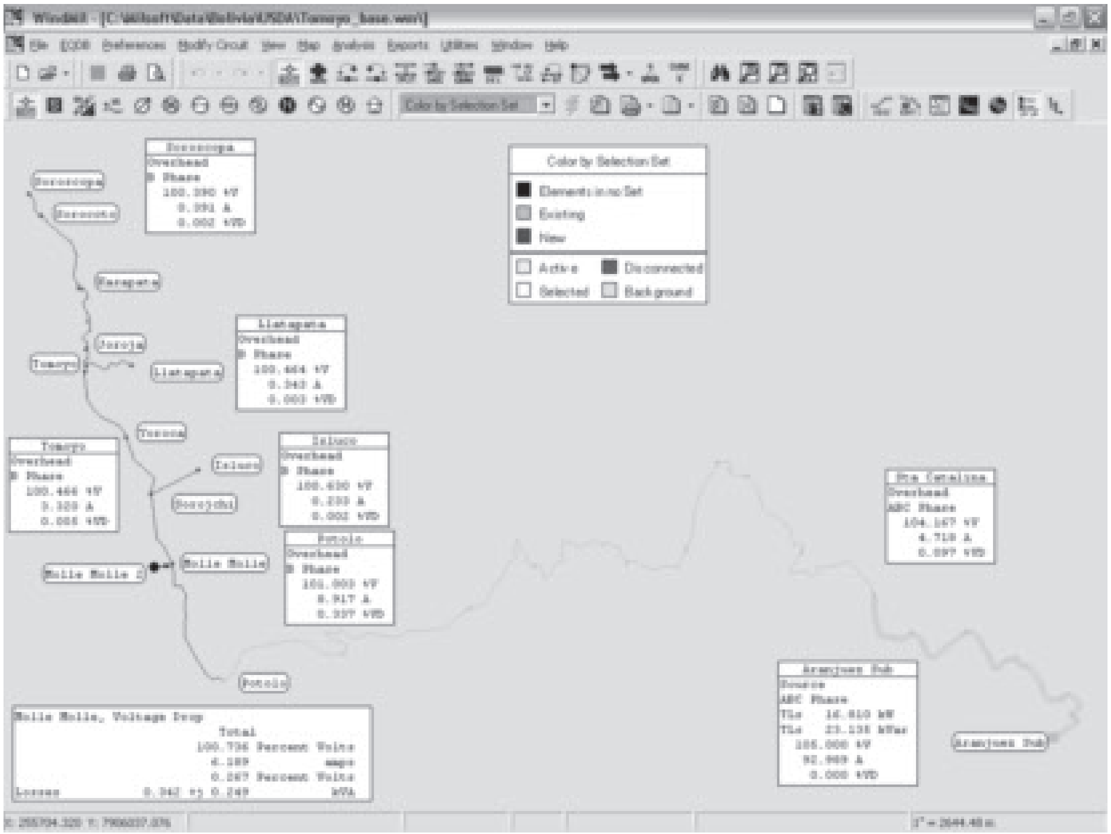


Figure 6. Sample three-line diagram of the power flow at year 20 (Tomoyo)

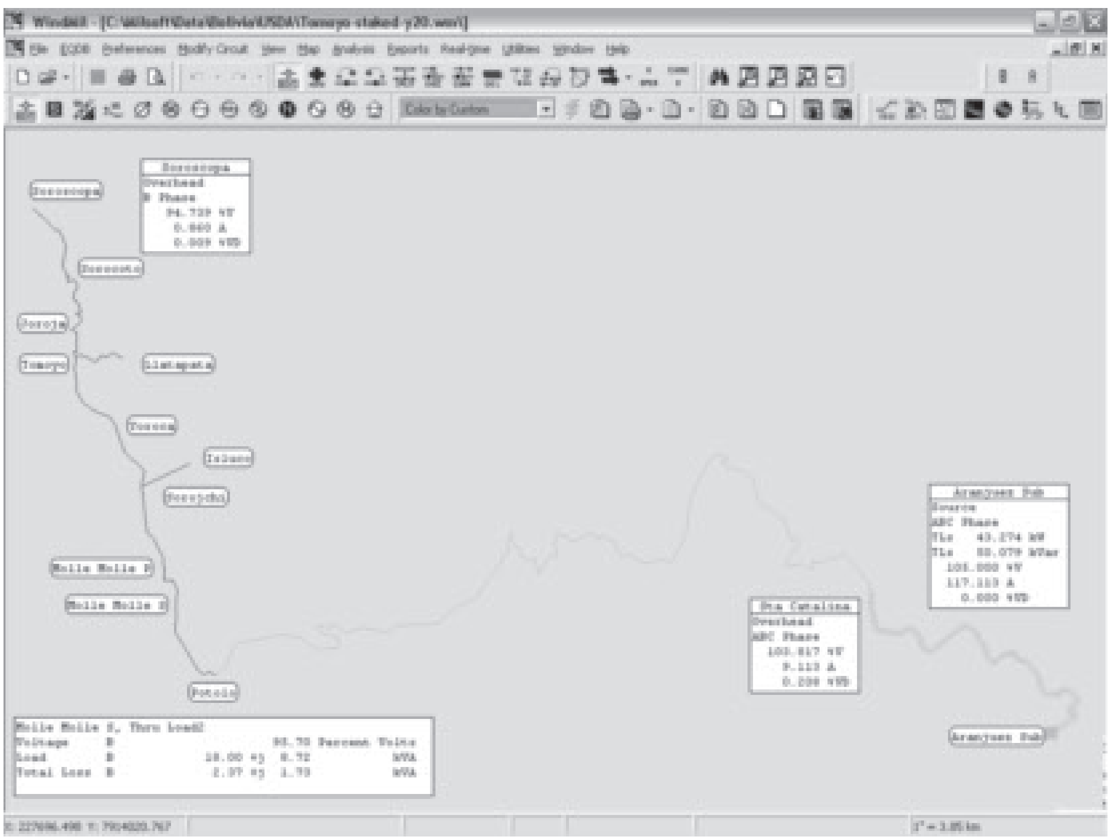
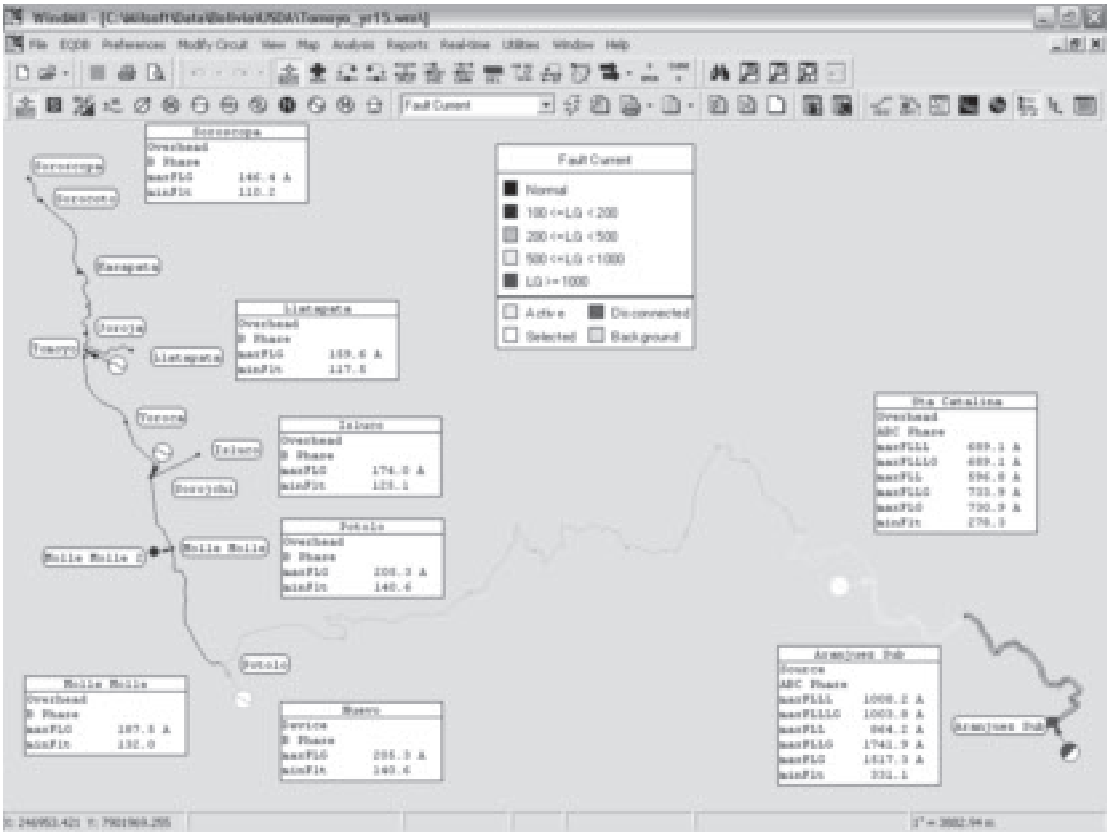


Figure 7. Sample three-line diagram of the values of fault currents (Tomoyo)



This database should include the unit price of each item of material, including the cost of shipment, and the total amounts for each purchase.

because some items differ according to their voltage level (insulators, transformers, etc.).

One must also consider taxes, if applicable to the project in question. Most projects financed with external aid are exempt from local taxes, but in other cases, one must determine the applicability of taxes and their amount. Another very important factor, in being able to apply historical costs to future projects, is the projection of the cost itself. The historical cost of materials may be projected to the future by using an inflation rate or a percentage of change in the cost of metals.[4]

Labor Database

Apart from a database for the cost of materials, the designer should maintain a database for the cost of labor, using the construction costs of previous projects. The costs on this database must be disaggregated by construction unit and not by kilometer, to be able to differentiate lines with different features. To apply historical costs to future projects, the engineer has to apply an inflation rate. Table 10 shows a typical format for a labor database.

Database by Construction Unit

The next step in determining project costs consists in calculating the investment costs by construction unit. Calculate these costs by adding the cost of materials for all the items included in the unit, plus the cost of labor for that unit. Table 11 shows a typical format for the database on cost by construction unit.

Database on Previous Designs

The engineer in charge needs to maintain another database on construction units by kilometer of line,

[4]A good database for metals is the London Metal Exchange at: http://www.lme.co.uk.

Table 10. Format for a labor database

Description of the Unit	Historical Unit Price	Inflation	Projected Unit Price

for the feeders between communities (called trunk lines or main feeders), and on construction units for distribution networks in the communities (i.e., taps off the primary line, transformation points, and low voltage distribution networks). The database for feeders between communities must include poles, primary structures, conductors, anchors and all the primary line hardware. The database on distribution networks for the communities must include all the units used in primary lines, underbuild, and secondary lines, and the transformation points in the communities.

In the database on feeders between communities, distinguish between three-phase and single-phase lines. Likewise, the database on feeders between communities must distinguish between lines in flat, level areas and broken terrain or areas with many line angles, because construction costs of electric lines differ greatly between these two types of land. Then, when going to the field, the engineer will evaluate the line to be built and will be able to determine its cost per unit.

Table 12 shows a format for a database on construction units by kilometer/feeder.

Database on the Costs of Service Drops

After developing the cost by kilometer of primary lines for feeders between communities and the cost by user for the distribution network in each community, develop cost estimations for the service drops. As in the preceding steps, base these estimations on a database of historical data, which includes the cost of materials and labor. There are various types of service drops to take into account, each with its particularities.

Apart from a database for the cost of materials, the designer should maintain a database for the cost of labor, using the construction costs of previous projects.

Table 11. Format for a database on cost by construction unit

Unit: ZA1			
Description	**Quantity**	**Unit Cost**	**Total Cost**
Square washer, 2-1/4″(5/8″)	3	$0.13	$0.39
Locknut, 5/8″	2	$0.11	$0.23
Spool insulator, 1-3/4″	1	$1.22	$1.22
Compression connector, ground to neutral	1	$0.33	$0.33
Preformed armor rods, single support, phase	1	$3.01	$3.01
Preformed armor rods, single support, neutral	1	$2.17	$2.17
Machine Bolt, 5/8″ x 10″	2	$0.55	$1.10
Spool bolt , 5/8″ x 10″	1	$2.43	$2.43
Pin-type insulator, ANSI 56-3	1	$30.22	$30.22
Pole top Pin , 20″	1	$3.68	$3.68
Aluminum tie wire, feet	15	$0.07	$1.04
Total Material Cost			$45.81
Labor Cost			$5.79
Total Unit Cost			**$51.60**

Table 12. Format for a database on construction units by kilometer

Unit	Quantity	Unit Cost	Total Cost
ZC1	71	$165.28	$11,734.65
ZC1-1	1	$310.71	$310.71
ZC2	9	$311.45	$2,803.08
ZC3	5	$221.28	$1,106.41
ZC6-10	2	$490.96	$981.92
ZC7-1	6	$230.48	$1,382.86
ZC7H	1	$259.57	$259.57
ZC8H	3	$422.10	$1,266.30
E1-2	49	$22.95	$1,124.64
E6-2	6	$38.80	$232.79
F1-12	61	$20.46	$1,247.79
M2-11	48	$17.71	$849.93
ZM3-3	1	$455.90	$455.90
ZM5-7	3	$42.79	$128.36
ZM5-18	1	$42.24	$42.24
Poste 11-6	78	$107.22	$8,362.93
Poste 12-6	10	$130.67	$1,306.73
Poste 13.5-5	6	$144.30	$865.79
1/0 ACSR	35,679	$0.55	$19,671.74
#2 ACSR	11,893	$0.46	$5,527.81
RM6	10,225	$0.44	$4,547.43
TOTAL			**$64,209.60**
Units 12Km			
Unit Price $5,398.94 /km			

Table 13 shows an example of a database on the distribution of different types of service drops.

Database on the Cost of Staking

The only cost component still to be determined is that of staking (design) of the proposed project. To have an idea of its cost, keep a database of the historical costs of staking in recent projects. This database must include the cost by kilometer for feeders between communities and the cost by user for the staking of the distribution network in each community. With this, the engineer can make a projection of the annual cost, taking into account an inflation rate. Table

Table 13. Distribution of different types of service drops

Type of Service Drop	K10M	K10E	K10L	K10P	K10P-X	TOTAL
Description	Fixed on wooden wall	Embedded in earth wall	Fixed on brick wall	On 6 m. pole	On 9 m. pole	
Quantity	414	494	530	3,122	180	4,740
Percentage	9%	10%	11%	66%	4%	100%

Table 14. Costs of electric line staking

Project	Cost/km	Cost/User
Nº 1	$218.76	$7.56
Nº 2	$248.25	$8.07
Nº 3	$246.90	$8.97
Nº 4	$222.22	$9.88
Nº 5	$195.00	$10.00
Nº 6	$215.00	$13.00
Average:	$224.35	$9.58
Inflation rate: 5%		
Projected:	**$235.57**	**$10.06**

14 shows an example of a database on the costs of staking.

Total Investment Cost of the Project

Upon arriving at this step, the engineer now has all the cost components necessary to estimate the total budget for the project.

Add these costs to the Excel worksheet described previously.

Table 15 shows an example of a worksheet that arrives at the total cost of the project.

Tables of Indicative Line Costs

To aid in calculations of project costs, Table 16 shows costs of projects recently carried out by NRECA in Latin America.

REQUIREMENTS FOR THE PRESENTATION OF THE PROJECT

After completing the electrical design of the project, as explained in *Project Design*, the engineer is in a position to estimate the total cost of the project, according to the section on *Estimation of project costs* of this module.

The engineer must next prepare the presentation of the project. This presentation contains a description of the project and a power flow, as explained in the previous sections. The description should contain many engineering tables or catalogues of materials, which add volume but do not assist in the description of the project.

Description of the Project

Keep the description simple, so it is useful for the evaluation of the project's feasibility. Table 17 shows a scheme for clarifying the description

There are various types of service drops to take into account, each with its particularities.

Table 15. Sample cost evaluation (Tomoyo)

Tomoyo	km	phases	users	KWh	kW	Staking	Feeder	Distribution	Total Cost	$/User
Molle Molle (ambos)	6.4	1	200	6,000	25	$4,723	$28,160	$94,000	$126,883	$634
Sorojchi	2.7	1	105	3,150	14	$2,240	$11,880	$49,350	$63,470	$604
Yoroca	2.5	1	98	2,940	13	$2,084	$11,000	$46,060	$59,144	$604
Tomoyo	4.2	1	114	3,420	15	$2,893	$18,480	$53,580	$74,953	$657
Llatapata	2	1	50	1,500	7	$1,326	$8,800	$23,500	$33,626	$673
Isluco	2	1	30	900	5	$1,086	$8,800	$14,100	$23,986	$800
Jiroja	1	1	60	1,800	8	$1,083	$4,400	$28,200	$33,683	$561
Kasapata	3	1	50	1,500	7	$1,689	$13,200	$23,500	$38,389	$768
Sorocoto	3.5	1	160	4,800	20	$3,191	$15,400	$75,200	$93,791	$586
Soroscopa	1	1	60	1,800	8	$1,083	$4,400	$28,200	$33,683	$561
	28.3	**10**	**927**	**27,810**	**121**	**$21,397**	**$124,520**	**$435,690**	**$581,607**	**$627**

Table 16. Costs of NRECA projects

	Bolivia	Nicaragua	Dominican Republic	Guatemala
Voltage Class	**35 kV**	**25 kV**	**15 kV**	**15 kV**
Three-phase US$ per km	$5,300	$9,534	$9,365	
Single-phase US$ per km	$3,100	$6,329	$5,472	$4,000

of the project. The numerical values correspond to the Tomoyo project.

Power Flow

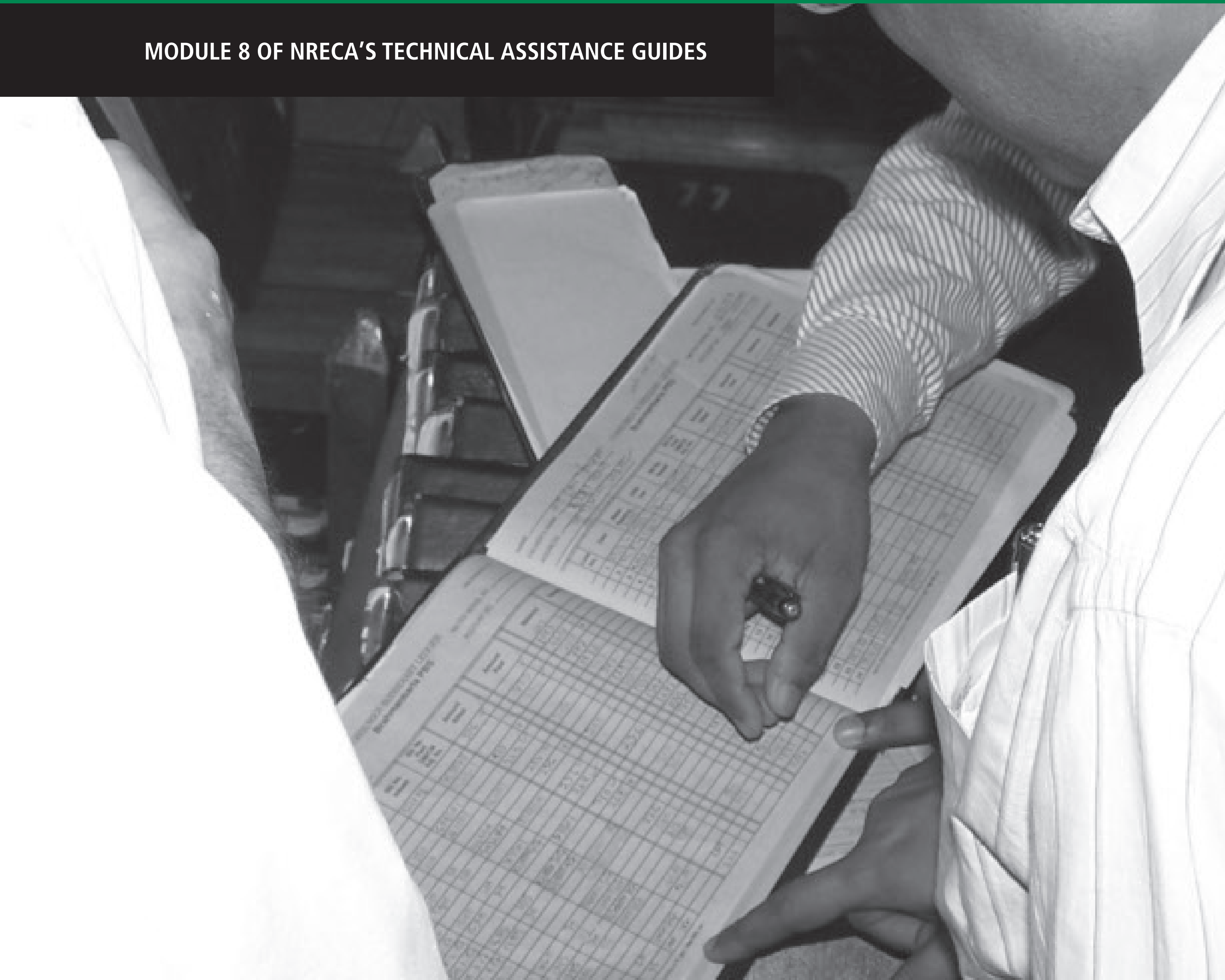
The power flow proves that the design is adequate for the project throughout the period evaluated. Consequently, there will be at least two power flows: one for the first year of the project and another for the last. A third power flow may be included when the study warrants the inclusion of some voltage regulation equipment during the life of the project, or during the time allowed for project analysis, so as to show where, when, and with what capacity this equipment is required to be installed. In these cases, the power flow should include a table of results showing the data for each point of the study and a three-line diagram that displays the results in a graphical format.

Table 17. Sample project description (Tomoyo)

Name of the Project	Tomoyo
Location of the Project	Department of Potosí
Names of the communities favoured	Molle Molle (ambos), Sorojchi, Yoroca, Tomoyo, Llatapata, Isluco, Joroja, Kasapata, Sorocoto, Soroscopa
Number of users favoured	927
Kilometers of primary lines	28.3
Primary voltage	14.4 kV
Number of phases	One
Section of conductor	#2 AWG ACSR phase and neutral
Estimated cost of parking	$21,397
Estimated cost of feeders	$124,520
Estimated cost of distribution networks	$435,690
Total estimated cost of project	$581,607
Estimated cost by user	$627

Financial Analysis of Rural Electrification Projects

MODULE 8 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



8

EXECUTIVE SUMMARY

This module presents a discussion of the role of financial modeling in rural electric utility project analysis. It includes a description and user guide for the NRECA Financial Model software tool specifically developed to evaluate financial performance of rural electrification projects developed by NRECA team members in Latin America, Africa, and South and Central Asia.

Projecting the financial viability of an electric system is essential in determining whether or not the project can attract financing and whether it will be able to reach financially sustainable operation. Determining financial viability involves weighing future cash outlays against projected revenues, with the goal of defining profit or loss attributable to the project.

The financial analysis process is iterative by nature, typically beginning with evaluating engineering design alternatives and their capital and operating cost estimates. In conjunction with preliminary engineering analysis, demand and sales models are developed, based on estimates of population and economic growth in the project area. The market assessment and engineering cost estimates influence one another so that any increase in expected sales may require increasing generation, transmission, and/or distribution capacity. In turn, the expected sales increases require increased capital and operating cost estimates. At the end of this iterative process, engineering and economic growth analyses optimize the project design to meet the best estimate of future market conditions. The base case projection helps planners evaluate project risks by varying key data values and underlying assumptions to determine project sensitivities and breakeven points.

The financial analysis process addressed in what follows includes input assumptions, scenario analysis, and model output. Note that the quality of the input assumptions to the model directly determine the quality of the output. Reasonable and accurate modeling requires attention to validating data values and verifying underlying assumptions. Scenario analysis tests data validity and can be used to bound future scenarios. So-called bandwidth analysis produces best, worst and most likely cases for the project. Sensitivity and breakeven analyses are further scenario analysis tools that can be help identify and evaluate project risks around ranges of possible values for certain key project parameters, such as the cost of debt, growth in sales, or the pricing of electricity. Detailed examination of financial model results facilitates evaluation of the base case and other scenarios.

This module presents a pro-forma model developed by the NRECA team as a means of providing a practical description of the concepts included in classical financial modeling.

The output section of the NRECA model has four main components:

1. Income Statement (showing revenues against expenses and resulting earnings)

2. Cash Flow Statement (comparing cash outlays against receipts)

3. Sources and Uses of Funds Statement (showing sources of cash across equity, subsidy, and debt against the destination of those funds for capital investment and operations)

Projecting the financial viability of an electric system is essential in determining whether or not the project can attract financing and whether it will be able to reach financially sustainable operation.

4. Project Indicators (showing project statistics and feasibility indicators including debt service coverage and internal rate of return)

The key data requirements of the NRECA model relate to the three categories of capital costs, market data, and operating costs, which are each discussed in some detail. The user guide provides step-by-step instructions on the use of the NRECA model. The output pages from a sample financial analysis (Cooperativa Electrica Fronteriza, Dominican Republic) are also included.

Rural electrification projects are generally evaluated on a time horizon of 10 years or more, because these projects require several years to complete the design, procurement, and construction cycle.

PROJECTING FINANCIAL VIABILITY

A key reason for the formation of rural electric cooperatives is that profit-making utilities often cannot economically reach and serve remote areas, especially where industry is limited and electricity consumption is low. Rural electric infrastructure is costly, and the decision to extend electric service to rural areas requires a careful balancing of costs and benefits.

In financial analysis, the cost side of the equation comprises the expenditure for new or additional electric facilities required to extend service, together with the expenses associated with operating expenses. Benefits derive from revenues resulting as a function of sales of electricity to consumers. Financial analysis uses spreadsheet-based anticipation (modeling) of future cash outflow and income associated with the proposed project.

Simplistically viewed, if project income exceeds operating costs, the project is financially viable, and if operating costs exceed income generated, the project is not financially viable. Rural electrification projects are generally evaluated on a time horizon of 10 years or more, because these projects require several years to complete the design, procurement, and construction cycle. Thereafter, additional time is required to connect customers and to generate sufficient revenue to cover operating costs of running the utility.

Results of financial analysis are presented via discounted net revenue and/or investment return indicators (return on equity, internal rate of return). These indices allow a numerical comparison of investment returns over the project time horizon. A standardized financial model allows the analyst to create scenarios and perform sensitivity analyses, taking into account sales and expense estimates, cost of capital, debt and equity investment ratios, and the effect of governmental assistance in the form of grants or subsidies.

Financial modeling provides decision makers with a picture of the financial viability of the proposed project. As with all projections into the future, financial modeling is neither infallible nor completely accurate. Modeling accuracy improves with careful estimation of capital and operating costs, as well as well-documented and conservative sales forecasts: the better the input assumptions, the more accurate the model.

The goal of financial analysis is to evaluate the profit or loss attributable to the proposed project. For marginal projects, the analysis should include a subsidy component. Governmental assistance, usually in the form of sharing the initial capital costs of the project, is justified by demonstrating the larger benefits to society resulting from the project. Such benefits go beyond those captured in financial analysis. They typically include savings to consumers on energy expenditures as well as employment, health, and environmental benefits (or costs). This broader definition of costs and benefits takes place in economic analysis, which is a step normally performed in cooperation with a government entity or development bank. The first step, however, is projecting the financial viability of the project.

THE FINANCIAL ANALYSIS PROCESS

Perform project financial analysis after capital and operating costs have been estimated for the project, and the business team has developed estimates of administrative operating costs and electricity sales.

It is common to evaluate multiple system design alternatives, which results in differing cost scenarios, which in turn can be evaluated in parallel with distinct sales projection scenarios. Sales projections are based on population and economic projections for the area. The sales projections may be affected by design alternatives that might extend electricity service to alternate villages and housing clusters.

Financial analysis is a method for evaluating and reviewing scenarios to determine the most viable system design for the community and for estimating the overall financial viability of the project. Analysts input data from the various scenarios into the financial model and tracking the relative viability of each design alternative.

Project analysis is therefore an iterative process. For example the financial model might show that the preferred system design is so costly that even the most optimistic market scenario does not generate enough income to support the project costs. When a given project shows very marginal returns, the analyst might choose to evaluate a design alternative that provides service to the most densely populated area only, with extensions to less financially viable areas to be added later. It may also be necessary to consult with project engineering personnel to request a re-evaluation of project design alternatives and costs, and thereafter reevaluate project viability.

Through this process, the most realistic market assumptions and the best project design become clear. Analysts can then focus on the financial analysis of the most attractive project scenario, then reconfirm all assumptions and cost estimates.

After refining the most viable scenario, the analyst can use the financial model to identify project risks and determine minimum feasibility requirements through sensitivity and breakeven analyses. At the end of the financial modeling process, the team has a higher degree of confidence in the viability of the project and is in a better position to discuss the project with the community and financial stakeholders.

Many analysts prefer to design and employ their own model and indeed often build a new model for each project to accurately capture the particularities of that project. There is no better way to fully understand the nature of the project than to spend hours structuring the financial calculations that describe the project cash flows. However, this approach runs the risk that the complexity of designing each new model may lead to undetected formulaic errors. Even an experienced financial analyst may work through several versions of a new model before clearing all errors. NRECA has balanced these issues by developing and making available a tested model specifically designed to analyze small rural electric grid extension projects.

Financial analysis is a method for evaluating and reviewing scenarios to determine the most viable system design for the community and for estimating the overall financial viability of the project.

Input Assumptions

"Garbage in, garbage out." – Wilf Hey

This well-known computer axiom means that if inaccurate data is entered into a computer program, the resulting output will also be inaccurate. For a financial model, the data input must reflect as accurately as possible the scenario being analyzed.

A financial analyst should have the habit of questioning, checking, and rechecking every bit of input. This means not only verifying the value of all input data but also validating the underlying assumptions – a subtlety that is often overlooked.

For example, let's say that we are studying an un-electrified area, and we have determined from household energy-use surveys that the current non-electrical energy consumption would be equivalent, on average, to 100 kilowatt-hours (kWh) per month. We might then assume that we can multiply the number of households in the community by 100 kWh to arrive at total residential electric sales.

While the data value of 100 kWh appears logical in this example, it depends on two assumptions that need to be validated. First, 100 kWh per customer may be an overstatement of future electricity consumption because not all current energy use will necessarily be supplied by electricity in the future. The more likely scenario is that some portion of current cooking (wood), lighting (kerosene), and entertainment (radio batteries) will use electric power. However, many community members may continue to use wood or charcoal for cooking. The second underlying assumption in the example is that all households would be connected to the system immediately, when it is more likely that consumers will join the electric service gradually and in accordance with their ability to pay for it.

The best and most accepted method of addressing uncertainties associated with projections and estimations is scenario analysis, also known as bandwidth analysis.

Thus the financial analyst must not only validate all input data values, noting the data source, but also make a conscious effort to identify and verify all underlying assumptions. This practice should apply to data generated by the project team (such as capital costs) as well as to those external to the project (such as population growth projections). When possible the analysts should use multiple data sources as a verification tool.

Remember that just because the financial model results are calculated and printed by a computer, it does not necessarily yield correct results. Before inputting the data, the financial analyst must check and validate all values and assumptions, and when variables change, check again.

Scenario Analysis

All rural electrification projects, and all investments in general, include some degree of uncertainty. Successfully bringing electric power to un-electrified communities is no exception. Success depends upon events and project participants who must come together in a coordinated and sustained fashion for the project to be successful. Any number of events can compromise project success, most likely not causing complete failure but resulting in only partially achieved targets. On the other hand, the project could go better than expected, with targets exceeded.

The best and most accepted method of addressing uncertainties associated with projections and estimations is scenario analysis, also known as bandwidth analysis. Scenario analysis consists of defining multiple, potential outcomes that will define a bandwidth around the most likely expectation of project performance. The analyst might evaluate a conservative case (e.g., high cost, low sales) and an aggressive case (e.g., low cost, high sales) that form a range of project results around the most likely outcome, or base case. This type of analysis adds comfort to the base case scenario that ultimately is presented in the business plan.

Typically, the business plan presents only the single, most likely scenario (referred to as the base case). However, it is sometimes beneficial to describe the low (conservative) and high (aggressive) cases in the business plan text to inform the reader of the range of possible project outcomes.

Analyzing a range of project outcomes helps to identify project risks. Since every project has some amount of risk, the best way to mitigate that risk is through evaluating and identifying mitigation strategies. For example, if it becomes clear that the most significant project risk is the industrial sales forecast, then this risk can be mitigated by coordinating the project with a community economic development program that supports industrial expansion through recruiting new businesses to the community.

In addition to bandwidth analysis, two other types of scenario analyses can help analyze risk, both of which are typically applied to the base case (not the high and low bandwidth cases). The first is sensitivity analysis where a single variable is changed among a range of possible values while all other variables are held constant, with observation of the resulting impact on the project outcome. The project outcome may be identified to be sensitive to changes in certain variables (those that produce a large change in project indicators) and not as sensitive to changes in other variables.

For example, the project outcome might vary little with changes in operation and maintenance expense (over a range of reasonable values) but vary greatly with possible shifts in the interest rate on project debt. As a logical follow-up, the analyst would increase the interest rate until the model shows revenues equating costs, that is, financial breakeven. Called breakeven analysis, this tool helps project promoters and prospective financiers understand the limits of the project with respect to specific key variables.

Model Output

The particularities of each project dictate which combination of the evaluation tools (bandwidth, sensitivity, and breakeven analysis) the analyst employs. All analyses may not be appropriate or useful in every situation. In any event, whatever useful information emerges from scenario analysis should be incorporated in the financial model description in the business plan. The model description in the plan generally focuses on the model results, or output. The output section of the NRECA Financial Model includes four main components, described below.

Income Statement

The Income Statement shows revenue for the project broken down by customer class, from which expenses (by major categories, the largest of which is typically purchased power) are subtracted. The net of total income less operating expenses is referred to by the accounting acronym EBITDA, or earnings before interest, taxes, depreciation and amortization. This measures the operational profitability of the project. A project that cannot cover operating expenses will not survive without operating subsidies, support that is not likely to be provided to most projects.

Next on the Income Statement, depreciation and amortization expenses are subtracted, resulting in EBIT, or earnings before interest and taxes. While depreciation is a non-cash expense, recovering the depreciation allowance is critical, as this represents the utility's reserve for plant replacement. Revenues sufficient to fund depreciation will allow for plant replacement, while failing to cover depreciation calls into question the long-term sustainability of the project.

Then, interest is deducted from earnings resulting, in earnings before taxes. If the project cannot generate sufficient revenue to service debt, then some type of capital subsidy or debt deferment will be required. Finally on the Income Statement taxes are subtracted, resulting in projected net income.

The Income Statement shows revenue for the project broken down by customer class, from which expenses (by major categories, the largest of which is typically purchased power) are subtracted.

Cash Flow Statement

The Cash Flow Statement presents cash receipts and expenditures. The first block in the statement shows the cash expenditure on capital items – the actual cash equity outlay (not the borrowed or donated portion) for a new or expanded electric plant in any single year.

The second block on the statement shows other cash adjustments, both outlays and expenditures. First, net income is carried over from the Income Statement, from which the actual cash outlay for principal payments on debt is subtracted (principal payments are not shown on the Income Statement) and depreciation is added back (originally expensed on the Income Statement, but actually a non-cash item). The result of these adjustments is net cash from operations.

Net cash from operations less cash outlay on capital items results in the annual net project cash flow.

Sources and Uses of Funds

The Sources and Uses of Funds statement presents a summary of the sources of project financing (equity, grant, or debt) and how/where funds are used (capital investment). This statement also presents a reconciliation of net cash from operations with cash sources from funding.

This statement begins with sources of funds and deducts uses of funds to result in net cash available, an amount that is carried over annually on the statement to show accumulated unburdened cash generated by the project (called "free cash flow").

Project Indicators

The final output section of the model presents a mix of project status data and project feasibility indicators, as described below.

Project Status

- *Energy Requirements (MWh)* – Annual amount of system energy requirements, defined as energy sales and energy losses
- *Coincident Peak (MW)* – Annual coincident peak demand, which is differentiated from billing or non-coincidental peak demand
- *Primary Line (km)* – Annual year-end number of kilometers of primary electric line constructed and operating
- *Households Served* – Annual year-end number of residential customers served
- *Population Coverage* – Annual year-end percentage of projected area population served

While the above data are intended primarily to provide descriptive statistics for the project over the forecast horizon, they can also serve as model integrity checks in that the existence of unexpected or outlier values generated by the model should be a signal that certain data or assumptions need to be checked.

Project Feasibility Indicators

- *Cash Return on Equity* – Annual cash generated as a percent of initial equity investment
- *Debt Service Coverage Ratio* – Ratio of earnings plus interest to debt service payment
- *Additional Working Capital Requirement* – Amount of additional working capital needed to cover projected operating deficits. If this number is greater than zero the analyst must return to the input section of the financial model and re-enter a higher level of working capital until this project indicator returns to zero
- *Internal Rate of Return on Equity (IRR)* – Standard measure of project financial viability reflective of the average annualized rate of return on equity generated by the project

Some of these indicators (especially Cash Return and IRR) are not always meaningful in the analysis of rural electrification projects, as a low equity investment (denominator) can skew the ratio of investment return. However, together with careful analysis of the output statements as described above (including earnings projections, funding of depreciation, debt service coverage, and net cash flow) these indicators make a full picture of the project's financial performance available to decision makers.

Rural electric cooperatives or utilities are sometimes established even when profits cannot meet the hurdles of commercial rates of return. Thus, the objective often results in identifying the means by which projects can successfully eliminate or minimize the need for governmental grant assistance.

FINANCIAL MODEL DATA REQUIREMENTS

Data collection is the first step in preparing the financial model for project analysis. This section provides an overview of the key data required by the NRECA Financial Model. Following this section is a user guide that offers specific step-by-step instructions for data input and model operation.

Capital Costs

Data in this category define the cost of constructing the proposed electric system. Arriving at this cost requires identifying the major system components, the number of each component required, and the cost of the component. All cost figures must include construction and installation as well as the cost of any land and civil work required (line right of way and substation). Note that these costs vary from project to project and should be adjusted to account for local material and labor costs.

Another item contributing to capital cost and required by the financial model is the cost of engineering design. In addition to engineering design costs, estimate any required pre-operating costs (preliminary engineering studies, etc.), in addition to projecting the tools, equipment, and vehicles that will be purchased for the project.

Finally, the model requires estimation of the capital structure of the project, identifying the grant, equity, and debt portions of the capital cost, along with loan terms.

The capital cost data must come from project-specific engineering studies, which include current local costs for materials and construction. Working together with the engineers, the financial analyst needs to pull the relevant data from the design studies and input it into the model. If costs for several design alternatives are presented, the analyst may use this data to evaluate multiple financial model scenarios.

Market Data

Market data define the target population and the size of the project market. The model requires a projection of the project population at the end of the planning horizon and an estimate of average household size. Population data are generally found at the government agency responsible for demographic statistics. Since government demographic data rarely identically match the geographical boundaries of a proposed project, interpolation of the data may be necessary.

Historical and projected population growth statistics provide the analyst a context for projections of residential customer growth. The model applies those projections to the initial customer connection estimates in the engineering study.

Data on the agricultural, commercial, and industrial segments of the market must be also be estimated and inserted into the model. These data are typically gathered through market surveys and/or studies on willingness to pay or energy end-use.

Data required by the model for each customer class include the number of customers, customer growth rates, and average monthly electricity usage.

Finally, tariffs for each customer class must be estimated and inserted, including customer, fixed monthly and energy usage charges. Pricing data are determined by such factors as customer willingness and ability to pay, the cost of providing service, the price of alternative fuels, neighboring utility pricing standards, and regulatory considerations.

Operating Costs

Data in this final input category define project operating costs. These include the cost of purchased power, customer expense, variable and fixed operations and maintenance expense, administrative and general expense, and professional services expense. The project engineer should provide estimates of operating costs, especially operations and maintenance expenses.

The capital cost data must come from project-specific engineering studies, which include current local costs for materials and construction.

The analyst generally estimates remaining costs through the "bottom up" method of identifying staff positions, applying competitive wages, and projecting related expenses.

Data from any existing area utilities of a comparable size and market situation may provide a useful guide. The model also requires data on projected collection efficiency, insurance costs, and corporate taxes (if applicable).

Financial modeling requires systematic estimates based upon data collection, as well as estimates based upon experience.

Summary

The analyst collects data in three categories: capital cost, market data, and operating costs. If the financial model analyzes multiple scenarios, then the values for certain variables will change accordingly, requiring supporting information for each new value of the variable.

Financial modeling requires systematic estimates based upon data collection, as well as estimates based upon experience. Arriving at reasonable estimates and relevant solutions is often an iterative process. After evaluating the data and the underlying assumptions, often after analyzing multiple scenarios, the analyst gains a "feel" for the project. This intuitive understanding of what drives the project results up or down, and identification of key sensitivities, should be used to determine which additional scenarios should be examined, with the goal of developing the optimal project structure.

FINANCIAL MODEL USER GUIDE

The NRECA Financial Model is an Excel-based spreadsheet developed as a part of this module. It analyzes the financial feasibility of proposed small, grid-connected rural electrification projects.

General Information

In the spreadsheet, white boxes indicate cells that require user input. Be careful to input data only in the white boxes and not in any other cells in the spreadsheet in order to avoid overwriting formulas. The spreadsheet cells are not edit-protected. However, a few of the input boxes are error-protected in the sense that a message appears if input is required but not yet entered.

The model is comprised of four sheets. The first is the Input sheet for entering nearly all the data required by the model. All input for monetary variables should be in U.S. dollars. The second is the Calculations sheet, an intermediate calculations section that allows the user to follow the model's logic and gain a better understanding of the financial projections. By illustrating the key drivers behind the numbers, the model also makes it easier to backtrack and locate input errors. The Results sheet follows the Calculations sheet, showing the financial projections in U.S. dollars, followed by the fourth and final sheet, Results Local, which shows the same results in local currency.

This module explains each sheet sequentially with primary attention on explaining the input required by the model. For best results, read the preceding modules of this publicaiton before using the model to carry out a financial analysis.

Following an explanation of the model presented here is a sample analysis of a rural electrification project in the Dominican Republic.

Input Sheet

SCENARIO NAME

The user should input a name for each scenario. The input name carries through the remainder of the sheets to differentiate the various models in scenario analysis.

A-1 Input Block: FEEDER, SECONDARY AND SERVICE COSTS

The total cost of materials and construction for single and three-phase line, in dollars per

Table 1. The A-1 input block

	A	B	C	D	E
	A-1 FEEDER, SECONDARY AND SERVICE COSTS				
7	Feeder Line		Single Phase	Three Phase	*Notes*
8	Total Cost Constructed (per km)		6,294	10,766	
9					
10	Secondary and Service				
11	Meter and Base		69		Service drop total (new and repaired equipment)
12	Duplex				
13	Cuadruplex				
14	Secondary and Transformer		179		
15	Transformer Bank			480	Three phase service drops
16	SECONDARY AND SERVICE TOTAL		$ 248	$ 480	

kilometer, goes into the A-1 input block, illustrated in Table 1. Note that values for medium voltage (Feeder Line) and low voltage (Secondary and Service) must be entered for single and three-phase components. These costs depend upon the quantity of material purchased and local construction costs.

Feeder Line

Enter the total cost, in dollars per kilometer, of constructing feeder, or primary line here.

Secondary and Service

Enter here, in dollars, the installed costs of the components of secondary and service drop – meter and base, duplex, quadruplex, secondary and transformer unit costs and transformer bank. The analyst can change the names of the components to fit the particular situation in Column A and add notes in Column E.

A-2 Input Block: TOTAL ELECTRIC PLANT COST

Enter here the remaining cost of the electric plant, excluding feeder, secondary and service costs already inputted in the A-1 block, along with other basic information needed to define the project. For each line item or component, be sure to enter the unit quantity and unit costs, unless already entered in block A-1.

New Construction

In column A, list all construction components for transmission and distribution construction with corresponding cost estimate for each. The user can change these construction components

Table 2. The A-2 input block

	A	B	C	D	E	F	G
	A-2 TOTAL ELECTRIC PLANT COST						
21		Materials,				Number	Extended
22	New Construction	Land, Civil ($)		Unit Definition		of Units	Cost ($)
23	Transmission Line			km 69 kV		-	-
24	Subtransmission Line	15,073		km 34.5 kV		18.0	271,314
25	Substations	560,200		1 @ 69/34.5 kV 1@ 69/12.5 kV		1.0	560,200
26	Step Banks/Regulators	161,843		2 @ 34.5/12.5 kV, regulator		1.0	161,843
27	3 Phase Primary	10,766		km 34.5, 19 kV		74.6	803,144
28	1 Phase Primary	6,294		km 7.2 kV		140.5	884,307
29	3 Phase Secondary/Service	480		secondary, service drop/meter		54	25,920
30	1 Phase Secondary/Service	248		secondary, service drop/meter		16000	3,971,894
31							
32	Average Depreciation Life	25	years		Existing System Acquired		-
33					Design and Engineering		
34		Year	$ Amount		Other Fees		-
35	Capacity Addition Required	7	1,000,000		Subtotal		6,678,621
36					Contingency %		0%
37	Plant Sized to Distribute to	16,000	# residential customers		Cost Contingency ($)		-
38	Total Projected Population	134,000	at end of planning horizon		Total Initial Fixed Assets ($)		6,678,621
39	Average Household Size	5.5			% Year 1, Trunk System		80%
40	Remaining Customer Base	8,364	unserved by initial plant		% Year 2, Balance of Plant		20%

or define them more specifically. Enter the per-unit cost for each item applicable to the project under “New Construction” in column B. In the “Unit Definition” (column D), enter a definition, or description, of the unit. For each line item, enter the number of units required by the project under “Number of Units” (column F). The resulting calculation, called the extended cost, automatically appears in “Extended Cost” (column G).

Where line item costs are not available and the analyst has only a total project cost, the total project sum should be entered in block A-1, cell C8 along with the value “1” in block A-2, cell F28. The total project cost will then be carried over to cell G28 by the formula. It is important that this convention be followed so that plant expansion costs are properly calculated. The plant expansion costs are based on initial construction costs, taken from cells G28 and G30 (single phase feeder line, secondary and service drop costs).

Existing System Acquired

Enter the acquisition cost (in dollars) of any existing electric assets that are purchased and that will become a part of the project in cell G32.

Design and Engineering

Enter the cost of system design and engineering (if not covered outside of the project) in cell G33. Enter any other fees and contingencies in cells G34 and G36.

% Year 1, Trunk System

The model assumes that the plant will be built within two years with, at a minimum, the trunk system built in the first year and the balance of the plant in the following year. Accurately calculating depreciation allowance requires the user to enter a value for the percentage of the plant completed in the first year in cell G39. Enter the value of 100% if construction will be completed in the first year.

Average Depreciation Life

Enter the number of years over which the electric plant should be depreciated in cell B32.

Capacity Addition Required

The model provides an option to include an additional, one-time discrete investment (e.g., for additions to the primary, backbone distribution line) in cells B35 and C35. In consultation with the project engineer, the modeler typically first examines customer growth projections. Later the analyst returns to this variable to enter the year and dollar amount of any additional investment required to expand the system backbone above and beyond the automatic investment additions made by the model so as to cover the cost of residential feeder extensions and service drops.

Number of Consumers

Enter the number of residential consumers in cell B37 (estimated from combining the acquisition of the existing system and new construction) to whom the electric system will provide service. Note that once projected customer growth surpasses the number of customers, the model automatically adds expansion investment, based on the ratio of the initial estimate of residential customers to the initial project investment in single-phase primary, transformers, secondary and service drop.

Total Projected Population

Estimate the total population of the service area projected by the end of the ten-year horizon in cell B38. Combined with an estimate of average household size (cell B39), this variable is used to calculate the remaining customer base (cell B40) in the service area. Cell B40 provides the number of residential customers that the project will not be able to supply in year ten of operations without further expansion.

The purpose of the estimate in cell B40 is two-fold. First, this indicates the portion of the market the project will serve in ten years without significant additional investment, and second, it can help prevent runaway customer growth projections resulting from invalid initial assumptions. Note that, as the model is structured to stop the growth of the number of residential class customers one year after the population cap is reached, it is important to review the interaction of this cap with the annual customer growth rate assumptions and adjust both as necessary.

A-3 Input Block: ADDITIONAL CAPITAL REQUIREMENTS AND CAPITAL STRUCTURE

In this block, enter additional capital costs of the project, along with data describing the means of project financing.

Equity per Member

Although this model was designed for electric cooperatives, it also applies to other, non-cooperative utilities. Part A-3 thus applies to cooperatives and non-cooperatives alike. Many rural electrification projects require member or consumer equity participation, often referred to as counterpart contributions to project funding. For projects that require membership equity or counterpart contributions, the analyst should enter the contribution here. Note that contributions can be received by the electric utility in a lump sum in the first year of the project or over time. If counterpart contributions are received over time, the terms of the contributions should be included here. Enter the dollar amount of individual membership dues/counterpart, followed by the payment term, annual interest rate, and the estimated percentage of residential customers who will contribute equity to the project.

Pre-Operating Costs

Enter any pre-operating costs that need to be capitalized, including project development expenses, consulting expenses, and other project "soft" costs, in cell G46 along with the number of years in the amortization period for this asset (cell D46).

Vehicles and Equipment

Enter the cost of utility vehicles and equipment (including office equipment and furnishings in cell G47, along with the amortization period (in number of years) in cell D47.

Initial Working Capital

Initial working capital is the amount of funds the utility needs to begin commercial operations, and that is "turned over" in one production cycle. Typically, the analyst leaves this cell blank until the model has been run with all other variables. Then, working iteratively by entering different amounts in this cell and reviewing the resulting project indicators on the Results page, the user can get a feel for the financial sensitivities of the project. Understanding gained by successive model iterations will likely suggest changes required to the capital structure of the project (the financial resources required by the project from equity, loans, or subsidies and grants), not simply the amount of working capital required.

Many rural electrification projects require member or consumer equity participation, often referred to as counterpart contributions to project funding.

Table 3. The A-3 input block

	A	B	C	D	E	F	G
	A-3 ADDITIONAL CAPITAL REQUIREMENTS AND CAPITAL STRUCTURE						
45							
46	Equity per Member	250.00	Amortization	5	< Pre-Operating Costs >		-
47	Payment Term (Years)	5	Depreciation	7	< Vehicles and Equipment >		343,097
48	Interest Rate %	5%			Initial Working Capital		
49	Member/Customer Signup	20%			Total Project Financing		7,021,718
50		%					
51	Grant	78%					
52	Co-op Member Equity	1%			78%	Grant	5,476,940
53	Private Equity	0%	Term	Rate	1%	Equity	70,217
54	Low Interest Debt	20%	15	6.0%	21%	Debt	1,474,561
55	Commerical Debt	0%	15	6.0%	100%	Total	7,021,718

Grant, Counterpart Contributions/Member Equity, Private Equity, Low Interest Debt, and Commercial Debt

The analyst distributes herein the total funds required for the project among five distinct sources: Grant, Co-op Member Equity, Private Equity, Low Interest Debt, and Commercial Debt. Also enter the loan term (number of years allowed to repay the loan) and the rate (annual interest rate, as a percentage). Even if the initial capital structure assumes no low interest debt, the user must enter the loan term and interest rate of such debt here, as these terms are used by the model to calculate the terms of financing for the future investment required to expand the system.

A-4 Input Block: ELECTRICITY SALES

In this block, illustrated in Table 4, enter sales data for each customer class and associated electricity usage and tariffs. The model allows for five customer classes, as well as street light sales.

For each customer class, the user must define the following tariff information. Note that it is acceptable to have no, or zero, charge in certain boxes, depending upon the project tariff structure.

Connect $/customer

This is the connection charge that each customer requesting and receiving a service connection must pay. It is a one-time charge assessed by the utility to all consumers.

Fixed Charge $/month

This is a fixed amount, in dollars per month, charged to every customer to cover customer-related fixed costs, and with no associated allowance for minimum energy usage. It does not include any minimum amount of energy usage.

Energy $/kWh/month

This is the amount charged per kWh consumed (in dollars per month).

Demand $/kW/month

Although not typically used in rural electrification in the developing world, the model allows the analyst to include a charge assessed per kW demanded per month, for all classes but the residential customer class. The charges may apply to a large industrial class and in situations where the utility will itself be subject to demand charges from its wholesale supplier.

For each customer class the user must define certain customer information.

Initial Customers

Enter here the number of customers served by the end of the first year. The number of residential customers is estimated by dividing the population of the project area by the average household size. There is no need to adjust the number of industrial and agricultural customers.

First Year Customers Average Months of Service

Enter the average number of months of electricity service received by customers in their first year as a member of the electric cooperative in cell I74.

No. of Customers % Increase per Year

Enter the estimated annual increase in the number of customers in three stages (Years 2-3, 4-6, and 7-10), to allow the model to project energy sales growth over the project life. Note that the growth rates are applied to the number of customers at the end of previous year.

Monthly Usage (kWh)

Enter the average monthly energy usage of each customer class.

Table 4. The A-4 input block

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
								A-4 ELECTRICITY SALES							
		Connection $/customer	Fixed Charge $/month	Energy $/kWh/month	Demand $/kW/month	Initial Customers		Number of Customers % Increase per Year		Monthly Usage (kWh)	% Increase Usage/yr	Load Factor	Non-Coincident Demand (KW)	Coincidence Factor	Coincident Peak (KW)
60							Years 2-3	Years 4-6	Years 7-10						
61	Residential		2.10	0.17		12,000	3%	7%	3%	121	3%	0.3	6,722	0.95	6,386
62	Commercial		3.26	0.17		450	3%	7%	4%	408	4%	0.3	850	0.75	638
63	Agricultural		3.26	0.17		50	2%	6%	1%	1,000	0%	0.4	174	0.75	130
64	Small Industrial (<50KVA)		3.26	0.14	22.40	2	3%	3%	2%	10,000	1%	0.5	56	0.80	44
65	Large Industrial (>50KVA)		5.62	0.14	10.95	2	3%	3%	2%	25,000	1%	0.6	116	0.85	98
66	Street Lights		3.26	0.12					Street Lights kWh/residential customer/mo.	0.7		0.5	24	0.95	23
67													7,941	0.92	7,319
68	Local Currency Name	Pesos	/US$ ex. rate	29.0						Initial Sytem Energy Sales (kWh)	211,700,880				
69			Pesos							Energy Losses (kWh)	9,073,234		Losses Converted to C- peak KW		2,954
70	Residential	-	60.90	4.93						Initial Energy Requirement (kWh)	30,244,114				
71	Commercial	-	94.50	4.93	-								Initial System C-Peak Demand (KW)		10,273
72	Agricultural	-	94.50	4.93	-								*(estimated - before reducing for customer phase-in)*		
73	Small Industrial (<50KVA)	-	94.50	3.94	649.600			First Year Customers Average Months of Service							
74	Large Industrial (>50KVA)	-	163.05	3.94	317.680				12						
75	Street Lights	-	94.50	3.51				*(applied to first year residential revenue for customer phase-in)*							

Table 5. The A-5 input block

	A	B	C	D	E	F	G	H	I	J	K	L	M
						A-5 OPERATION COSTS							
81		Cost/kWh	Cost/Peak-KW		Insurance as %		Non-Pass Through		Applicable				
82	Purchased Power	0.1	9.9	U$	of Plant Cost		Sales Tax		Income Tax				
83		2.2	287.7	Pesos	1.0%		3%		0%				
84													
85	Customer & Variable O&M	9.00	$/customer	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
86	Fixed O&M	83,000	$ annual					Billing Collections Efficiency					
87	Fixed A&G	24,000	$ annual	60%	80%	90%	92%	93%	94%	95%	96%	96%	96%
88	Fixed Professional Services	20,000	$ annual					Technical and Non Technical Energy Losses as % of Total Supply					
89	Fixed Cost Real Inflator	3.0%	% annual	30%	15%	12%	12%	12%	12%	12%	12%	12%	12%

% Increase Usage/Yr

Enter the estimated annual increase in average monthly electricity usage for each customer class.

Load Factor and Coincidence Factor

This section asks for information related to load factor and coincidence factor. Note that this data is not likely to be available for a new project. Therefore, unless the analyst can obtain reasonable estimates for the specific project under review, we recommend that the values in the spreadsheet be used without further changes. These figures are based on experience and are within normal limits of rural utilities. To discourage changes to these values, these cells have been shaded.

These variables allow the model to produce estimates of billing demand and coincident system peak demand. Helpful indicators (e.g., peak load) on this input block provide real-time feedback as to the characteristics of the system being modeled.

Finally, the analyst can include the name of the local currency and its exchange rate with respect to the U.S. dollar. This allows the user to view tariffs in local currency as well as in U.S. dollars, and to produce an output page in local currency.

A-5 Input Block: OPERATION COSTS

The final input block, shown in Table 5, allows the user to define the utility's operating costs.

Purchased Power

Enter the cost of purchased power in dollars (incorporating any wheeling charges) in cells B82 and C82, for energy and, if applicable, monthly peak demand, respectively.

Customer & Variable O&M

Enter customer expense and variable operations and maintenance expense (calculated in dollars per customer, per year) in cell B85.

Fixed Costs

In cells B86-87, the analyst should enter the annualized fixed operations and maintenance costs (Fixed O&M), fixed administrative and general costs (Fixed A&G), and the fixed cost of professional services, such as legal and accounting services (Fixed Professional Services). The spreadsheet program inflates each of these categories by the amount entered in cell B89 (Fixed Cost Real Inflator) to produce annual figures for each year in the planning period. The fixed cost real inflator is the estimated average rate of inflation for the period in question.

Insurance as % of Plant Value

The figure entered in cell E83 represents the cost of insurance as a percentage of the value of the assets insured. The program applies this figure to the value of the initial insurable electric plant to calculate annual insurance expense.

Non-Pass-Through Sales Tax

The figure entered in cell G83, expressed as a percentage, denotes sales tax levied against the cooperative's total revenue. Do not fill this in if the utility will simply charge customers for sales tax and pass on the tax received to the government authority.

Applicable Income Tax

The figure entered in cell I83, expressed as a percentage, is the rate that will be applied to any positive net income to calculate corporate income tax expense.

Collections Efficiency

The figures entered (as a percentage) in cells D87 through M87 represent the amount of revenue collected as a proportion of the total amount billed to customers. The spreadsheet uses these values to calculate the project's estimated annual revenue from four customer classes – Residential, Commercial, Agricultural, and Small Industrial.

The spreadsheet uses these values to calculate the project's estimated annual revenue from four customer classes – Residential, Commercial, Agricultural, and Small Industrial.

Technical and Non-Technical Energy Losses

The figures entered in cells D89-M89 reflect total estimated energy losses, calculated (and entered into the spreadsheet) as a percentage of total energy purchases.

Calculations Sheet

Most of the major calculations are performed on this page, although some are also carried out on the Results page. The formulas for the calculations are not error-protected. However, changes to the formulas are not recommended. If changes are required, take extreme care to ensure that the implications of the change throughout the entire model have been thoroughly considered.

B-1 CUSTOMER GROWTH

This calculation block tallies customer growth per year and by customer class. New customers are italicized so that their connection charge can be applied later in the revenue calculations section. The customer numbers in this block do not show the application of the population cap, which appears elsewhere.

B-2 ANNUAL kWh SALES

This block calculates annual energy sales before any reductions for first-year customer phase-in. (The reductions, based on the first-year customers' average months of service, occur on the Results page.)

B-3 MONTHLY N-C BILLING DEMAND

This block calculates non-coincidental peak, or billing, demand. The model then applies it to the appropriate customer class.

B-4 MONTHLY C-PEAK DEMAND

In this block, the system coincidental peak demand is applied to the wholesale power tariff for non-residential customers, where appropriate.

B-5 POPULATION SERVED

The number of residential customers is multiplied by the average household size to calculate the population served. This figure is used on the Results page as a cap on estimates of customer growth.

B-6 KM LINE

This block calculates the ratio of initial kilometers of line constructed to the initial number of customers. The resulting indicator appears on the Results sheet. This indicator is subsequently used to determine the additional kilometers of line required to serve additional customers once the full capacity of the original system has been reached.

B-7 PLANT VALUE

This block calculates the value (in dollars) of plant expansion required by the increase in customers beyond the initial system capacity. This value forms the basis for calculating depreciation of the plant, or the project's fixed assets. Note that plant value, for the purpose of calculating depreciation, is that portion of the plant acquired through equity and debt financing, not any contribution to plant acquisition financed through grants or subsidies.

B-8 PAYMENTS ON EXPANSION PLANT DEBT

This block uses the values calculated in Block B-7 to calculate additional interest and principal repayments resulting from debt-financed expansion of the electric plant.

B-9 IRR STREAM

The project's Internal Rate of Return (IRR) is calculated here and copied to the Results sheet.

B-10 MEMBER EQUITY PAYMENTS

This final block calculates equity capital contributions by cooperative members.

Results Sheet Reminders

The Results sheet was discussed earlier. Items worthy of mention, or repetition, include the following:

- The results sheet is calculated in both U.S. dollars and in local currency. Note that in the local currency version, the user must enter how values expressed in local currency should be displayed. For example, to show 1,000 units of the local currency in nominal terms, the user should input "1" and 1,000 will be displayed. To express 1,000 units as a multiple of 10, enter "10," and 100 will be displayed. The same 1,000 units will appear as 10 if the number 100 is entered, and so on.

- On the Income Statement, the acronym EBITDA stands for "earnings before interest, taxes, depreciation, and amortization." EBIT stands for "earnings before interest and taxes."

- In the Project Indicators box, the analyst should note that any nonzero value for the variable "Additional Working Capital Requirement" signifies a cash requirement for operations that is not included in the project capital structure entered earlier. As noted in the commentary above, the user must work iteratively with this and other indicators to structure the project's financing so as to fund the project's entire cash requirement (working capital).

- Since there is a one-year delay in stopping the growth of the number of customers in the residential class (based on the preset population cap), the Project Indicators box may show a population coverage that exceeds 100 percent. It is also possible that residential sales will continue to increase after the population cap is reached if the "average sales per customer" variable is set to increase annually in the Input sheet. As long as increases in average usage per customer were intended, the continued increase in total sales is correct even after surpassing the population cap.

NRECA FINANCIAL MODEL – SAMPLE PROJECT

Tables 6, 7, 8 and 9 illustrate one of several scenarios analyzed for the Cooperativa Electrica Fronteriza in the Dominican Republic. This scenario projects a significant unfunded working capital requirement. Part of the purpose of the scenario was to identify that amount so as to be able to negotiate various possible solutions, including increased grant assistance, softer loan terms, and preferential power rates.

Table 6. Results: Income Statement (Cooperativa Electrica Fronteriza)

SCENARIO — Fronteriza - Indexed Tariffs — US$										
INCOME STATEMENT										
Revenue	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential	1,958,688.0	2,763,154.0	3,289,197.0	3,696,106.0	4,107,507.0	4,564,477.0	4,882,432.0	5,222,288.0	5,527,957.0	5,851,870.0
Commercial	235,284.0	335,469.0	403,601.0	458,373.0	514,827.0	578,200.0	631,130.0	688,866.0	744,090.0	803,780.0
Agricultural	62,373.0	84,827.0	97,339.0	105,473.0	113,016.0	121,085.0	123,147.0	126,147.0	127,409.0	128,683.0
Small Industrial	28,591.0	39,657.0	46,411.0	49,354.0	51,900.0	54,571.0	56,816.0	59,147.0	60,933.0	62,772.0
Large Industrial	96,949.0	100,720.0	104,779.0	109,002.0	113,395.0	117,964.0	121,525.0	125,195.0	128,976.0	132,871.0
Street Lights	12,584.0	12,961.0	13,348.0	14,280.0	15,277.0	16,344.0	16,833.0	17,336.0	17,855.0	18,390.0
Total Revenue	2,394,470.0	3,336,790.0	3,954,678.0	4,432,592.0	4,915,927.0	5,452,647.0	5,831,890.0	6,238,987.0	6,607,229.0	6,998,376.0
Expenses										
Purchased Power	3,264,624.0	2,958,446.0	3,051,679.0	3,357,145.0	3,693,720.0	4,064,601.0	4,312,783.0	4,576,634.0	4,857,166.0	5,155,452.0
Operations & Maintenance	83,000.0	85,490.0	88,055.0	90,096.0	93,417.0	96,220.0	99,106.0	102,080.0	105,142.0	108,296.0
Customer & Variable O&M	112,545.0	115,917.0	119,389.0	127,740.0	136,674.0	146,234.0	150,662.0	155,224.0	159,926.0	164,771.0
Administration & General	24,000.0	24,720.0	25,462.0	26,225.0	27,012.0	27,823.0	28,657.0	29,517.0	30,402.0	31,315.0
Professional Services	20,000.0	20,600.0	21,218.0	21,855.0	22,510.0	23,185.0	23,881.0	24,597.0	25,335.0	26,095.0
Insurance	66,786.0	66,786.0	66,786.0	66,786.0	66,786.0	66,786.0	66,786.0	66,786.0	66,786.0	66,786.0
Sales Tax	71,834.0	100,104.0	118,640.0	132,978.0	147,478.0	163,579.0	174,970.0	187,170.0	198,217.0	209,951.0
Total Expenses	3,642,789.0	3,372,063.0	3,491,229.0	3,822,825.0	4,187,597.0	4,588,428.0	4,856,845.0	5,142,008.0	5,442,974.0	5,762,666.0
EBITDA	(1,248,319)	(35,273)	463,449.0	609,767.0	728,330.0	864,219.0	975,495.0	1,096,980.0	1,164,255.0	1,235,710.0
Depreciation & Amortization	87,468.0	97,081.0	97,081.0	97,081.0	97,081.0	97,081.0	137,854.0	94,691.0	100,717.0	106,924.0
EBIT	(1,335,787)	(132,354)	366,368.0	512,686.0	631,249.0	767,138.0	837,641.0	10,002,289.0	1,063,537.0	1,128,786.0
Interest on Initial System	88,474.0	84,673.0	80,643.0	76,373.0	71,845.0	67,047.0	61,960.0	56,568.0	50,853.0	44,794.0
Interest on Expansion System	-	-	-	-	-	60,548.0	66,634.0	72,453.0	77,967.0	
EARNINGS BEFORE TAXES	(1,424,260)	(217,026)	285,726.0	435,713.0	559,402.0	700,091.0	715,134.0	879,087.0	940,232.0	1,006,025.0
Income Taxes	-	-	-	-	-	-	-	-	-	-
NET INCOME	**(1,424,260)**	**(217,026)**	**285,726.0**	**435,713.0**	**559,402.0**	**700,091.0**	**715,134.0**	**879,087.0**	**940,232.0**	**1,006,025.0**

Table 7. Results: Cash Flow Statement (Cooperativa Electrica Fronteriza)

C-2 CASH FLOW STATEMENT										
Capital Expense	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Initial Plant	70,217.0	-	-	-	-	-				
Expansion Plant	-	-	-	-	-	-	10,193.0	1,463.0	1,507.0	1,552.0
Total Cash Equity Expense	70,217.0	-	-	-	-	-	10,193.0	1,463.0	1,507.0	1,552.0
Cash Adjustments										
Net Income	(1,424,260)	(217,026)	285,726.0	435,713.0	559,402.0	700,091.0	715,134.0	879,087.0	940,232.0	1,006,025.0
Less Principal Payments										
Initial System	63,351.0	67,152.0	71,181.0	75,452.0	79,979.0	84,778.0	89,865.0	95,257.0	100,972.0	107,031.0
Expansion System	-	-	-	-	-	-	43,355.0	52,177.0	61,716.0	72,019.0
Plus Depreciation	87,468.0	97,081.0	97,081.0	97,081.0	97,081.0	97,081.0	137,854.0	94,691.0	100,717.0	106,924.0
Net Cash from Operations	(1,400,143)	(187,097)	311,625.0	457,341.0	576,504.0	712,393.0	719,768.0	826,343.0	878,261.0	933,900.0
ANNUAL CASH FLOW	(1,470,360)	(187,097)	311,625.0	457,341.0	576,504.0	712,393.0	709,575.0	824,881.0	876,754.0	932,348.0

Table 8. Sources and Uses of Funds (Cooperativa Electrica Fronteriza)

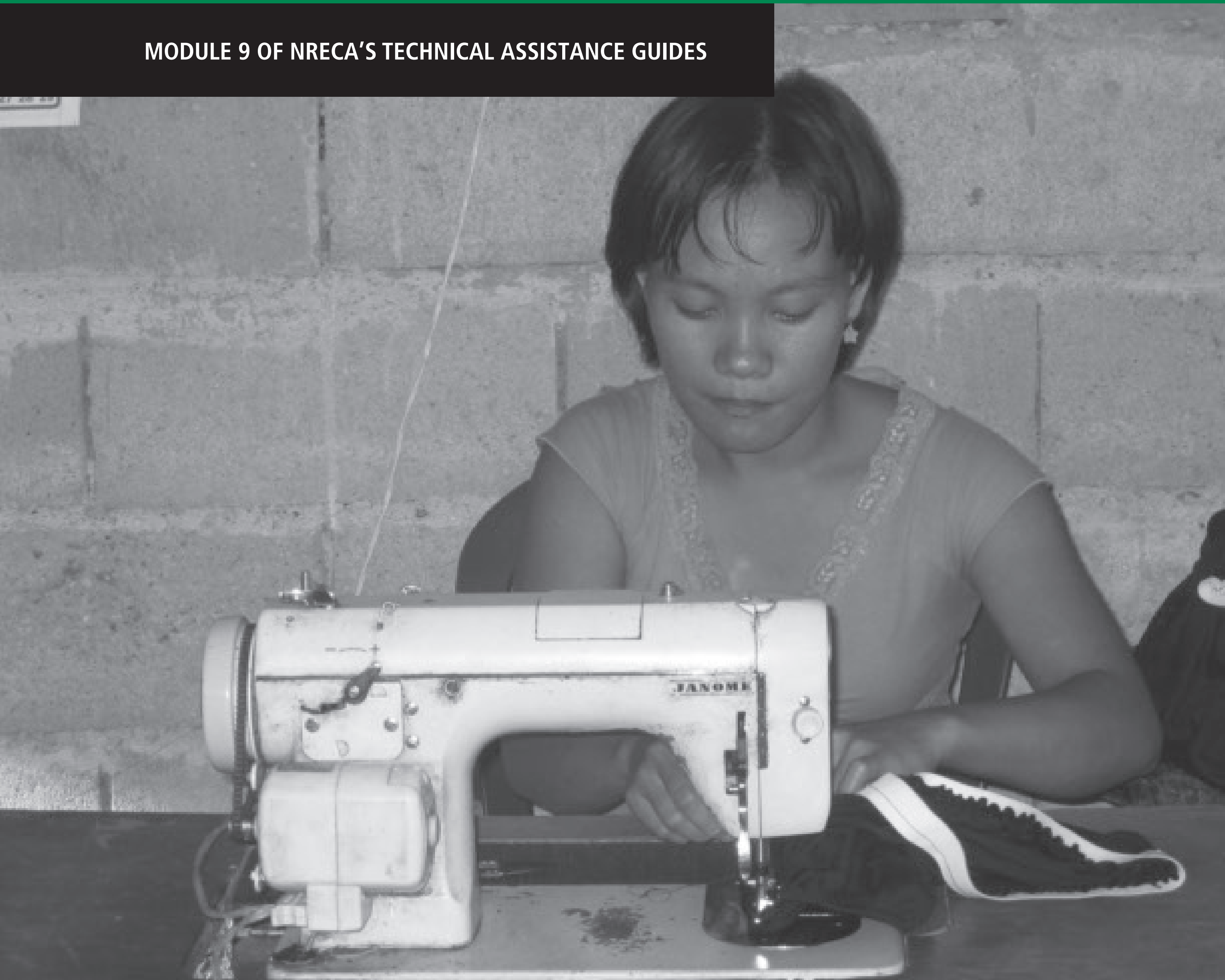
C-3 SOURCES AND USES OF FUNDS										
Project Financing	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Grant	5,476,940.0	-	-	-	-	-	-	-	-	-
Equity/Capital Reserve	70,217.0	-	-	-	-	-	10,193.0	1,463.0	1,507.0	1,552.0
Debt	1,474,561.0	-	-	-	-	-	1,009,126.0	144,803.0	149,147.0	153,621.0
Total	7,021,718.0	-	-	-	-	-	1,019,319.0	146,266.0	150,654.0	155,173.0
Member Equity Payments	12,934.0	86,477.0	90,331.0	99,799.0	110,041.0	37,966.0	29,580.0	39,799.0	35,790.0	31,172.0
Cash from Operations	(1,400,143)	(187,097)	311,625.0	457,341.0	576,504.0	712,393.0	719,768.0	826,343.0	878,261.0	933,900.0
TOTAL SOURCES	5,634,509	(100,620)	401,956	557,140	686,545	750,359.0	1,768,667.0	1,012,408.0	1,064,705.0	1,120,245.0
CAPITAL INVESTMENT	7,021,718	-	-	-	-	-	1,019,319.0	146,266.0	150,654.0	155,173.0
NET CASH	(1,387,209)	(100,620)	401,956.0	557,140.0	686,545.0	750,359.0	749,348.0	866,142.0	914,051.0	965,072.0
ACCUMULATED CASH	(1,387,209)	(1,487,829)	(1,085,873)	(528,733)	157,812.0	908,171.0	1,657,519.0	2,523,661.0	3,437,712.0	4,402,784.0

Table 9. Results: Project Indicators (Cooperativa Electrica Fronteriza)

C-4 PROJECT INDICATORS										
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash Return on Equity	-1975.6%	-143.3%	572.4%	793.5%	977.7%	1068.6%	1052.7%	1231.4%	1299.6%	1372.2%
Debt Service Coverage Ratio	(8.2)	(0.2)	3.1	4.0	4.8	5.7	3.8	4.1	4.1	4.1
Energy Requirements (MWH)	30,244.0	26,397.0	27,025.0	29,718.0	32,684.0	35,951.0	38,139.0	40,466.0	42,939.0	45,569.0
Coincident Peak (MW)	8.4	8.2	8.6	9.5	10.4	11.5	12.2	13.0	13.7	14.6
Primary Line (km)	215.0	215.0	215.0	215.0	215.0	215.0	216.0	222.0	229.0	236.0
Households Served	12,000.0	12,360.0	12,731.0	13,622.0	14,575.0	15,596.0	16,064.0	16,546.0	17,042.0	17,553.0
Population Coverage	49%	51%	52%	56%	60%	64%	66%	68%	70%	72%
Additional Working Captial Requirement	1,487,830 <<Caution! This cash requirement is not funded. Iteratively adjust Initial Working Capital on Input sheet									
Internal Rate of Return on Equity	23.7%									

Productive Uses of Electricity

MODULE 9 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



9

EXECUTIVE SUMMARY

Many national governments have committed significant financial resources to bring modern electric services to rural communities. Many families who live within reach of electric service, however, have learned to do without. This is primarily due to their inability to pay for service, which deprives them of a source of entertainment, security, and income generation.

The "productive use of electricity" concept assumes that electricity improves the competitiveness of rural enterprises. Within the framework of the concept, the electric cooperative or energy service provider becomes a promoter of rural enterprise, which in turn generates consumer goods and services, increases employment, and enhances the local economy. In developing countries, promoting the productive uses of electricity is an activity that host governments and rural communities cannot afford to ignore. Rural communities are part of a globalized world, full of risks and opportunities, where only the most competitive businesses survive.

This module presents a series of methods, tips, and recommendations that reflect approaches NRECA has successfully deployed throughout the world. These experiences have inspired the implementation of productive uses of electricity programs in several countries. Based on the lessons learned, this module identifies six key components for a successful productive uses of electricity program, which are:

1. Access to a reliable electric service
2. Access to a local market for goods and services
3. Availability of electric equipment
4. Access to financial resources
5. Qualified human resources
6. Coordination and promotion

NRECA's productive uses model integrates numerous variables, including efficiency and safety of designs and equipment, feasibility, social and environmental responsibility, and coordination among the players involved. It emphasizes creating an environment of trust and encouraging the participation of the community in all phases of the projects. This module provides concrete steps for the design of a productive uses of electricity program. It includes direction for initial information gathering; identification of participants (institutional and business owners); structuring of training strategies; options for obtaining technical assistance; financing options; selection of tactics pertinent to the unique conditions of the target area; sensitivity to sociocultural variables; and ways to achieve the inherent productive potential available.

A productive uses of electricity program is a basic tool for electric cooperatives and companies to move towards greater sustainability. It also helps governments to increase the common good and enables communities to achieve equitable development and improve their economic viability. The success of NRECA-supported productive uses programs in many countries has validated the approaches described in this module which place high priority on having local participants effectively promote the program and which emphasize sensitivity toward the predominant conditions in the target regions.

A productive uses of electricity program is a basic tool for electric cooperatives and companies to move towards greater sustainability.

INTRODUCTION

Background

Determining, developing, and implementing a feasible rural electrification project remains a key challenge for most developing country governments and for the institutions that carry them out. The level of electricity consumption and willingness to pay are two issues affecting project feasibility. An electric system's feasibility increases the more energy it sells to its consumers, as long as the tariffs cover all costs (for both current operation and future needs) and the consumers are able and willing to pay for what they consume. The "productive uses of electricity" (PUE) concept promotes the creation and growth of productive activities, ranging from micro-businesses to heavy industry. The greater the number of PUE's created or expanded, the greater the amount of electricity consumed. As profit margins expand for PUE owners, the more money they have available to consume electricity and pay electricity bills. Thus, as the paying capacity of consumers grows, revenues for the electric distribution cooperative or utility also grow.

The "productive uses of electricity" (PUE) concept promotes the creation and growth of productive activities, ranging from micro-businesses to heavy industry.

There are six major components fundamental to the success (or failure) of PUE programs:

1. Access to modern energy service
2. Market conditions
3. Availability of electric equipment
4. Financial resources
5. Human resources
6. Coordination and promotion

Other factors also exist that can have a marked influence on the success or failure of a PUE program. These include the legal and regulatory landscape as well as the host country's political, economic and social stability.

This module provides guidelines for the design, implementation, and evaluation of a PUE program, so that it benefits both the consumers and the electric distribution company, electric cooperative, private electric distribution company, or governmental entity responsible for electric service.

Definitions

Though its source is unknown, the simple definition often cited by the authors for a productive use of electricity is "Any use of electricity that generates income for the user."

A broader definition is the use of electricity for the common good. The common good includes productive development in any sector, including potable water, public lighting, education, health, etc.

Objectives and Scope

The purpose of this module is to help electric distribution utilities (whether cooperatives or other institutional models) implement a PUE program, where improvements in administrative efficiency and technical expertise are expected to increase profitability. NRECA prepared this module as part of a series of technical guides that promote financial and technical sustainability for distribution systems and electric cooperatives, with the goal of offering reliable, accessible, and sustainable electric service. This module can also aid governments in justifying the significant financial investment required for rural electrification, through the promotion of productive uses of electricity, as detailed in what follows.

Although this module is intended for use in developing countries, with consideration of the characteristics of the PUE sector inherent in each region, the fundamentals of its methodology may be useful to any electric distribution entity in the world.

JUSTIFICATION FOR A PRODUCTIVE USES PROGRAM

Many rural distribution systems or cooperatives require a conscious effort to promote productive uses of electricity for the distribution entity to justify their costs, and/or sustainably generate profits. Many electric grid expansion projects or electric generation investments in rural areas cannot be justified economically, unless a productive uses of electricity approach is used as a tool to spur development and generate new sources of income. Modern energy services are also an essential component of increased access to social and economic benefits for rural areas.

Historically, rural electrification projects have often been conceived solely as social investments. Projects of that nature are deemed complete once inaugurated, since their purpose is to primarily bring light to un-electrified residential homes. The concept of electricity as a development initiative has typically not been a driving force in decision making or prioritization of rural electrification projects.

A change of paradigm occurs, however, when decision makers establish the concept that rural electrification is not an end but a means. That implies that generating improved business competitiveness through productive uses of electricity will translate into better income, better community services, and in general, a better opportunity for integrated development. The addition of complementary development efforts, such as support infrastructure, education, training, technical assistance, and access to credit form part of this new development initiative. Together with the electric distribution system, the development efforts serve as a foundation for growth.

Productive uses of electricity programs have grown out of the notion gained though experience that access to electricity alone does not generate employment or increase income in rural areas. However, an economically depressed population will not have the capacity to pay the distribution company's tariffs without increased access to appropriate means to augment their income. Thus, a market-oriented productive uses of electricity program, which uses local resources and local labor, will promote business competitiveness and accelerate the learning process related to employing electricity as an economic stimulus for the target area.

COMPONENTS OF A PRODUCTIVE USES PROGRAM

The basic components of a PUE program include access to modern energy service, favorable market conditions, availability of electric equipment, financial resources, human resources, and coordination and promotion. What follows is a fuller discussion of these components one by one.

Access to Modern Energy Service

Productive uses activities require energy to produce goods or provide services. In addition, the energy needs to be reliable. A classic example to illustrate the importance of reliable electric service is an ice cream shop. No power, no more ice cream. Modern energy service reliability, both in continuity of supply and power quality, is key to assuring users that they will get a return on their investment and that their commercial and residential electric equipment will work safely and efficiently. Moreover, consumers must have confidence that excessive voltage fluctuations will not occur, which could damage their electric equipment or force users to disconnect the equipment to avoid damage or malfunction.

Distribution cooperatives or utilities have an obligation to meet minimum standards of service. They should of course strive to go beyond those minimums to meet customer expectations of quality and service. Put another way, distribution entities should be customer-oriented, with a focus on satisfying the needs and concerns of

Generating improved business competitiveness through productive uses of electricity will translate into better income, better community services, and in general, a better opportunity for integrated development.

their consumers. As part of customer service, they should ensure that the electric consumer is well informed.

Favorable Market Conditions

Even if all of the other components of a PUE program are in place, if the market cannot or is not willing to absorb the increase in products and services, the program will fail. For example, if a small business pottery manufacturer gets excited about participating in a PUE program, it might well be able to increase production tenfold. Yet if a mere threefold increase in supply exceeds maximum market demand, the newly expanded business is not likely to survive.

Even if all of the other components of a PUE program are in place, if the market cannot or is not willing to absorb the increase in products and services, the program will fail.

Electric service providers are typically not the entities that initiate marketing studies or identify new products that could be developed through the use of electricity. Most of the time distribution utilities join forces with a non-governmental organization to educate the potential program beneficiaries in the basic aspects of demand, supply, pricing, and analyzing market competitors, as well as the commercialization of goods and services. This educational effort should be directed to both local and national markets, depending on the nature of the new products and services. If an organization decides to promote a particular product through a productive uses of electricity program, that entity must also be in charge of carrying out the corresponding market study to help ensure successful program results.

Availability of Electric Equipment

A productive uses of electricity program promotes the use of electrical equipment and tools in commercial or industrial production. Consequently, the program should provide information and resources about where to acquire the equipment, the variety of models available (with different technical specifications), and financing options. In some cases, promoting the use of electrical equipment can be a simple coordination task with existing vendors in the program vicinity. In other cases, a strategy is needed to promote the availability of electrical equipment vendors. Alternatively, the distribution utility itself could assume responsibility for supplying the desired equipment. There are numerous approaches for bringing electric equipment providers and potential consumers together, including fairs, mobile demonstrations, promotional talks, mass media, and other marketing initiatives.

A successful PUE program identifies the best way to ensure that equipment is available and accessible to the beneficiaries of the program, using methods that are sensitive to consumers' income level and socioeconomic condition, while keeping in mind the country's legal system and regulations.

At the outset of a PUE program, it may be necessary for the implementing entity to guide the consumer in selecting of equipment, considering the unique aspects of each business and prevailing market environments. Vendors should be encouraged to provide technical assistance and information regarding the purchase of their equipment. However, until electrical service is well established, the implementing entity should actively coordinate the technical assistance required between vendors and consumers.

Although electrical equipment can be of significant benefit when it is properly operating, it also has inherent and serious dangers. Therefore, the PUE program must provide technical assistance and training to consumers, educating them on how to locate, select, acquire, install, operate, and maintain their equipment in a safe and efficient manner. Depending on the size of the target population and program budget, it is important to consider the depth of technical assistance that can be reasonably offered by the PUE program. It is advisable to coordinate efforts with other institutions that could assist in providing technical assistance to PUE program participants, such as universities, mid-level educational institutions, training centers, schools, business owners, equipment providers, artisan-teachers, financial institutions, non-governmental organizations (NGOs), and other educational and developmental institutions.

These institutions can also contribute to disseminating technical information to the general population, especially with regard to safety and the benefits of modern energy service.

Financial Resources

Once the program beneficiaries are aware of the program possibilities, the market offerings, and the investment in equipment and working capital required, the program should turn its attention to financing options. In some cases, PUE beneficiaries may have their own capital ready to expend. However, a majority will likely require some form of credit to obtain the necessary equipment. To maximize program success, the PUE program should therefore provide information regarding available financial resources.

To finance the purchase of electrical equipment, it is necessary to involve financial institutions that are willing to participate in the PUE program. However, prior to defining alliances with a particular financial entity, it must be analyzed. Program implementers should examine the main indicators of institutional solvency, as well as resource availability, bad debt rates, customer service policies, and other operational aspects considered important to the implementation of a PUE program. Regional differences exist. Some programs have had successful experiences with rural creditors, while others have experienced failures. Therefore, it is important for the PUE program team to carry out due diligence on the various lending institutions before selecting program allies.

Another financing option is granting credit to PUE beneficiaries interested in connecting to the electric grid or in making improvements to their existing electrical installations to reflect the current standards of the country. Implementers should keep in mind that in some cases, consumers may require financial support to cover both the cost of connecting to the electric distribution system and the acquisition of electrical equipment.

Human Resources

Each productive use activity needs to have people with the skills necessary to make the business survive, and better yet, to thrive. There may be reliable electricity, available electric equipment and financing, and a favorable market, but if the business does not have the human resources required to operate it sustainably, it is doomed to fail. Here again, the program implementers must decide how much training the program itself will have to provide versus using existing institutions such as vocational schools, technical institutes, universities, and NGOs.

For the program itself to succeed in designing a productive uses program, those involved must understand the entire program, how and why it was conceived and its design, goals, and objectives. Personnel involved in the program should not only have a clear understanding of the project, but also be sensitive to the circumstances that prevail in the target population.

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It may be worth designating one or more full-time field professionals to work directly with the projected program consumers and vendors. The field professionals can promote ties among potential program consumers and coordinate with the electric utility, as well as with credit institutions and vendors. The appropriate level of human resources needed naturally relates directly to the program's scope and magnitude. The financing institution must equally designate qualified personnel to provide advice to consumers on equipment purchases, and to formalize financing contracts with their new clients. Depending on the volume of PUE participants and projects, the PUE promoter may advise the financing institution to establish an office in the target area of the program. All professionals involved in the productive uses program must be sensitive to the socioeconomic conditions and cultural diversity of the program beneficiaries.

Coordination and Promotion

During the design of the productive uses program, it is important to develop a clear strategy for coordinating the program's implementing entity, the electric distribution entity (which could be or could later become the implementing entity), the financial institution, the equipment vendors, and the consumers or beneficiaries of the program. How the program is to be coordinated depends on the consensus reached regarding expectations and responsibilities of each entity, as well as expectations of the program beneficiaries, the consumers.

A productive uses of electricity program is usually considered a complementary part of a larger rural electrification program.

A PUE program may have ambitious objectives and creative approaches, but the intended participants must become familiar with it to take advantage of it. Appropriate program marketing, oriented to local conditions, is exceedingly important for current and potential consumers of the electric service to learn how to work with the various PUE institutions, and how to participate actively in the program.

Periodically monitor and survey the program's promotion tactics and media, so as to determine whether marketing tactics and strategies are reaching users and whether any modifications are necessary.

In El Salvador and Guatemala, NRECA employed mobile demonstration units for productive use demonstrations. The mobile units, outfitted with a variety of electric tools, equipment, and appliances, arrived in targeted communities to demonstrate what can be accomplished when using electricity productively. Simple educational materials on topics related to safety, efficiency, business management, and the benefits of electrification were distributed during these presentations. Project teams found that these mobile demonstration units had a great impact on children and adults. However, the decision to use mobile demonstrations take into account the cost/benefit of the investment (cost of the mobile unit, equipment, etc.) and the cost of travel and personnel.

Another approach is to display electric equipment in operation at existing businesses. In this situation, coordinators of the PUE program identify proprietors who are willing to host a demonstration for interested parties at their place of business. Through prior arrangement, other potential entrepreneurs are invited to visit the business and experience first-hand the benefits of the demonstrated electric equipment.

PRODUCTIVE USES OF ELECTRICITY PROGRAM DESIGN

A productive uses of electricity program is usually considered a complementary part of a larger rural electrification program. PUE programs have also been successfully employed in communities that have long been electrified. In either case, a productive uses program can propel the development of micro, small and medium-sized enterprises.

General Objective

In the design of PUE programs, the standard stated objective of the program is to structure a program strategy, in conjunction with the rural electrification project, which helps integrate technical and financial efforts to promote and/or accelerate the productive, efficient, and safe use of electricity in target communities.

Specific Objectives

Specific objectives of a standard PUE program are as follows:

- Identify and bring together the various individuals and entities working to support economic development in the target region.
- Implement a needs assessment and identify existing productive activities in the target area.
- Sensitize all program individuals and entities (including the target population) to the financial,

economic, social, and environmental benefits obtainable through the implementation of a productive uses of electricity program.

- Seek input from all local players in developing the program design and action strategies related to promotion, technical assistance, and financing.
- Be sensitive to the productive, socio-economic, ethno-cultural, and environmental conditions of the target region.

Scope of a Productive Uses Program

To define the scope of a PUE program, implementers should conduct an initial study of the target communities and inventory the existence and capabilities of potential stakeholders. The study should evaluate each of the six basic program components described in this module. Using the Human Resources component as an example, the initial study would determine how well prepared the owners of potential beneficiary microenterprises are to manage, operate, and expand their businesses; how many, if any, vocational schools, technical institutes, universities, and NGOs exist; how many of these institutions could effectively train the personnel of the beneficiary productive use activities; and how many, and to what extent, these organizations could help coordinate the program in general. Based on the results of the study, the implementers would decide what type of training the beneficiaries need most and who would provide it, thus defining the scope of the human resources component of the program.

Applying the same process to each of the components and putting the whole picture together would define the overall scope of the PUE program. Assigning costs and benefits to various potential program activities and analyzing the various options allows planners to prioritize activities according to the greatest financial, economic, and social benefit. With that information, the program implementers can adjust the program scope to obtain the greatest benefit from the resources available to execute the PUE program.

Program planners should bear in mind that the sustainability of the program may hinge on how effectively they involve existing organizations from the start. The program scope should, by design, involve commitments in both finances and personnel on the part of the stakeholders (electric utility, credit institutions, equipment vendors, educational institutions, and beneficiaries) to the greatest extent possible.

To define the scope of a PUE program, implementers should conduct an initial study of the target communities and inventory the existence and capabilities of potential stakeholders.

Active participation by the electric service provider, educational centers, NGOs, and government entities is important for the success of the program. Strategic involvement of these players will help to institutionalize the program within the respective entities, inducing positive changes and the momentum necessary for a sustainable program.

Identification of the Players and their Roles in the Program

A productive uses program involves a number of stakeholders or players that are essential to its success. Table 1 shows a typical list of PUE project players within a community.

Success in development programs comes from combining the efforts of various players. Consequently, establishing parallel and related development initiatives (such as the improvement of the public water system) along with the PUE program can be useful. Implementers must remember to coordinate these efforts with the various players.

Program Strategies

A PUE program can embody, or complement, a larger strategic plan for the economic development of a community or a region. The strategic plan should comprise methods of providing training, technical assistance, and financing.

Table 1. PUE program players and activities

Player	Activity Carried Out
Proprietors of current micro, small and medium enterprises or potential commercial consumers of electricity	Represent the PUE sector, which uses electric energy as a productive input into current and/or potential processes
The electric distribution cooperative or utility	Provide reliable, safe, and financially accessible electric service to the beneficiaries of the program
Financial sector entities (formal and informal)	Provide financial services (credit and financial analysis)
Equipment vendors	Facilitate access to electric equipment and provide related technical assistance
Technical assistance providers	Governmental or non-governmental entities that create or strengthen technical capacities within the target communities
International aid agencies and/or other public or private organizations	Organizations that channel technical, financial and/or in-kind resources to support economic growth

A training strategy acquaints the community with the many applications of electricity as a way to make commercial/industrial processes and production more efficient.

This module emphasizes the empowerment of each player, especially the project beneficiaries within the PUE sector. The goal is to empower the local population to make decisions in their own best interest, through the transfer of knowledge, education, training, and the proper tools.

Training Strategy

A training strategy acquaints the community with the many applications of electricity as a way to make commercial/industrial processes and production more efficient. The players assigned educational responsibilities must decide how best to provide training on basic electricity and utilization of electric equipment, along with providing specific technical assistance. The financial institution(s) involved in the program should also provide financial services training.

Community Training

Community training should take place in each of the target regions. It should be directed at two levels of the population: the economically productive population and the student population.

Such trainings normally take place at a community meeting, which informs the population of the technical and financial effort involved in the electrification of their community (assuming the PUE program is being carried out as part of a greater rural electrification project). The meeting would also discuss opportunities created by electrification, using comparisons with other non-electrified communities. In an area where electric service already exists, the community training should also take place at a community meeting, discussing the technical and specific details of the PUE program, as well as the electric service needs in the area.

Training resources may include audiovisual material, educational modules, dramatizations, and/or direct demonstrations of the application of electricity in diverse activities commonly carried out in the community. Implementers should offer separate training opportunities for groups that show a greater interest and require more in depth details, as well as for school-aged children.

NRECA has developed mobile demonstration units that become a main source of attraction in community trainings. These units are typically electrically self-sufficient, so that they succeed as training tools in non-electrified communities and communities with poor power quality. The mobile demonstration units are effective in motivating families to consider productive uses of electricity.

To efficiently use limited financial and technical resources, any training strategy should focus initially on the main community centers, and then extend progressively outside the major population centers, until the entire target region has been reached.

Community trainings involve all program players, i.e. community leaders, neighbors, the implementing entity, the local electric distributor, the financing entity, equipment suppliers, and other local entities.

The following set of steps illustrates how community training activities can be coordinated and promoted.

1. Select the project region and communities in a coordinated manner, involving all players, so as to meet the objectives of the program.

2. Promote community PUE training through contact with local leaders. The community training objective is to inform the population regarding the PUE program. Therefore, the support of local leaders is needed to identify the most appropriate training location and to select and convene the participants.

3. Choose the date and hour of the community meeting with the aim of ensuring the greatest level of local population participation.

4. Place promotional banners and posters in strategic locations within the community. Make house-to-house calls, and depending on the local customs, arrange for a vehicle with a loudspeaker to travel throughout the community announcing the activity in the local language, emphasizing the date and hour of the meeting.

5. Before carrying out the community training, prepare a detailed report to identify existing and potential PUE activities. Share this information with the electric equipment vendors and with participating financing agencies.

6. Conduct the community meeting and training following a previously prepared agenda. Take the names of participants who are interested in equipment or financing. End the meeting with an announcement stating the dates and times for upcoming special meetings for those individuals interested in acquiring equipment and for those interested in receiving financing.

7. Hold special sessions on electric equipment and financing opportunities to introduce equipment and financing options, including the associated costs.

8. Finally, set up and carry out personal appointments with individuals interested in discussing details of equipment or financing, with assurances that the plans and/or financial situation of each individual will be kept confidential.

Commercial Management Training

The second phase of the PUE program's training strategy is designed specifically for individuals interested in creating new businesses or in strengthening existing businesses. The objective is to teach best management practices and share methods that improve administrative efficiency and business productivity.

The second phase of the PUE program's training strategy is designed specifically for individuals interested in creating new businesses or in strengthening existing businesses.

This educational effort promotes the active participation of the players involved. Its successful implementation improves business sustainability for those involved. The following suggestions make the management training more effective.

Training Prior To Financing And Business Startup

Before loans are made or equipment is purchased for new businesses, this training provides an opportunity for financing entities and equipment suppliers to become more familiar with potential customers and to identify those who have a defined project compatible with the philosophy of the PUE program and a qualifying credit history. In this phase to the program promoter should share enough detailed information with the productive uses entrepreneurs to allow them to make an informed decision regarding whether or not to participate in the PUE project.

This training consists of two sessions, as follows.

All training must be sensitive to the participants' educational levels and cultural backgrounds.

Content of the first session:

- General program introduction and objectives
- Who are we? Introduction of participating parties and explanation of their roles
- Distribution of information regarding financing options and commercially available equipment
- Definition and discussion of financing
- Planning business requirements, based on production, administration, and existing and potential markets

Content of the second session:

- Introduction
- Managing credit effectively
- Preparing and complying with a work plan
- Forming a support committee to help the business succeed

The sessions should be scheduled to have the greatest possible benefit. For example, the second session could take place after customer credit approval, but before disbursement of the loan. In order to avoid business failures, implementers should consider postponing credit disbursement or equipment delivery until the entrepreneur or customer participates in the second session.

Training For Existing Businesses

This training is for individuals who already have existing businesses and who may or may not be interested in obtaining loans. The training content concerns improving management of productive uses of electricity activities and includes both required and elective courses.

Required courses: These courses provide a basic understanding of how to run a business and are a prerequisite for those that want to apply for financing:

- Simple accounting (accounting for non-accountants)
- Budgeting and cost control
- Basic administration
- Basic marketing

Elective courses: Offered after completion of the required courses. Topics are generated to meet the individual customer's specific needs, and can be defined when such needs are identified.

Typical elective topics include:

- Strategic planning
- Organization
- Efficiency and safety
- First aid

All parties interested in acquiring financing or obtaining a special discount from equipment vendors must participate in the required training, and a selection of elective courses, selected in consultation with the PUE trainers.

All training must be sensitive to the participants' educational levels and cultural backgrounds. It should emphasize creating a business that will be competitive in a market-driven economy (whether local, national, or international). The training provides beneficiaries with information and methods that can help contribute to ongoing business success.

Training Associated with Financial Service Entities

Small and medium-sized enterprises often lack access to traditional financing mechanisms. The financial services infrastructure is often concentrated within urban centers and has minimal outreach to rural areas. Also, frequently rural business proprietors and those interested in started a business have little documentation regarding their identity and assets (equipment, land, productive infrastructure). Therefore, they do not have acceptable collateral or proof of credit worthiness.

To address this issue, a portion of the productive uses training program should focus on working with financial entities to expand their programs to reach entrepreneurs who are eager to begin or expand productive use activities but lack access to credit.

Financial services trainings are usually oriented towards lending agencies, although they could also include others such as equipment vendors involved with the program.

The recommended approach is to conduct a workshop for formal and informal financial institutions, such as small local microcredit programs. This training aims at sensitizing financial entities to include rural enterprises in their financing programs. The training ultimately helps to introduce rural inhabitants to, or expand their knowledge of, the credit sector and its potential as a catalyst for rural development. By combining credit with access to electricity, these two inputs can become major drivers of rural economic development.

Often financing organizations already work with productive uses in urban or peri-urban areas. Nevertheless, these organizations frequently lack the basic knowledge of how to properly assess and reduce the risks inherent in loans even in those populated areas. They are even more likely to lack the knowledge of how to effectively extend their services to rural areas. Therefore, the training program should address the fundamentals of sound credit assessments as well as best practices for offering loans to rural clients.

Technical Assistance Strategy

The technical assistance strategy for the PUE program's business participants provides credit seekers with the necessary technical support for the selection, purchase, use and maintenance of electric equipment. It also helps with the design, execution, and maintenance of their electric installations and provides the marketing support needed to promote their goods and services.

The availability and scope of technical assistance varies, depending on the scope and magnitude of the PUE program. The electric cooperative, electric equipment vendors, financial institutions, or an institution specialized in providing training could each be the provider of such assistance. The technical assistance may include the following components.

Pre-Financing Technical Assistance

Pre-financing technical assistance support goes to individuals who are interested in the PUE program but have not received credit or have not acquired equipment. Technical assistance during this phase relates to three areas:

Selecting the Best Equipment for the Job

PUE program promoters who are familiar with the equipment needs of participants should explain the reasons for and at least three price quotes for the desired equipment and assist with obtaining them.

The assistance must emphasize the importance of obtaining quotes from recognized companies

By combining credit with access to electricity, these two inputs can become major drivers of rural economic development.

that guarantee the equipment, offer a competitive price, quality, spare parts, and maintenance. The objective is to gather sufficient information to compare the advantages and disadvantages of various equipment options, so the potential user has sufficient information to select the option that best responds to their needs. The implementers should convey the message that the final equipment selection decision is the responsibility of the entrepreneur alone.

The PUE participant must receive training regarding requirements for electric equipment installation and maintenance.

Support During the Equipment Purchase to Obtain the Best Deal and Warranty

After selecting the necessary equipment, the PUE promoter helps make the arrangements necessary to facilitate the purchase. This may include supporting the entrepreneur in financial dealings with the financial institution and/or accompanying the individual during the payment process. The PUE promoter must verify that the equipment selected is received with all accessories, manuals, and warranties and must verify that the equipment meets the specifications quoted by the vendor.

Basic Orientation on the Correct Use of Equipment

Commonly, equipment vendors are responsible for educating the buyer on the correct operation and maintenance of the equipment purchased. Additionally, the vendor should provide detailed information regarding the performance characteristics of the equipment. The information should include minimum requirements for electric installation (conductor size, protective devices, grounding, etc.) and other characteristics of the working environment, (ventilation, temperature, minimum safety considerations, lighting, etc.). Such training enhances the safety of the operators and keeps them from voiding warranties.

Post-Financing Technical Assistance

Post-financing technical assistance comes into play immediately after credit has been granted or after the equipment has been installed. It involves support for the entrepreneur through a direct relationship with the PUE promoter, who provides support primarily via site visits to the business. Through observation, appropriate suggestions are made for improving weak areas of operation. In addition, the PUE promoter can arrange for specialized trainings with other entities, if needed.

Assistance in the post-financing phase concentrates on activities such as the following.

Equipment Installation

The PUE promoter must orient the businessperson regarding the following:

- Suitability of the location where the machinery or equipment will be installed for the nature of the equipment
- Arrangement and setup of the equipment, based on space required and production needs
- Equipment installation according to manufacturer's requirements
- Lighting and ventilation needs to guarantee operators' safety
- Integration with other equipment and production processes

Electric Installation

The PUE participant must receive training regarding requirements for electric equipment installation and maintenance. The implementers should consider carefully the protection of operators and equipment. Whenever possible, a qualified technician, following the electric utility's standards, should carry out the electric installation. Where no national standards exist, base the installation on the United States National Electric Code to avoid potential warranty issues. In addition, take the following into account:

- Use quality materials and accessories (according to safety standards).

- Create and properly execute an installation plan to ensure that the equipment is correctly insulated and installed according to standards.

- Make sure all electric circuits where equipment will be connected meet the appropriate protection and safety standards.

- Keep the medium voltage circuits out of reach of people and machinery.

- Install dedicated circuits and independent protection for special equipment.

- Ensure that all installations are physically grounded.

- Install equipment so technicians can easily access equipment for maintenance.

Equipment Protection

Protecting equipment is of vital importance, because it is typically the business's most valuable asset. Train the PUE recipient to follow these practices:

- The work area should be orderly and clean, particularly where electric installations are located.

- Make all connections with equipment designed for the specific corresponding purpose.

- All equipment must be disconnected and switches turned off when the equipment is not in use.

- Cover all equipment when it is not in use. If the equipment is mobile, it must be kept clean and in a locked location.

- Install equipment in a secure and safe environment, stored in a place of business, rather than in a residence or other location where unauthorized access to the equipment is possible.

Maintenance of the Equipment/Machinery

The PUE promoter must verify that the entrepreneur is carrying out the correct maintenance indicated in the manuals and recommended by the vendor. The business supervisor must oversee that the following steps are taken:

- Clean equipment at the end of each workday.

- Lubricate and grease parts as required, according to the manual.

- Periodically inspect circuits, conductors, connections, protection, and switches.

- Examine and maintain such things as belts, tensioners, shock absorbers, augers, blades, bearings, and support and positioning mechanisms, in accordance with the manufacturer's recommendations.

- Monitor ventilation conditions, illumination, space layout, waste, odors, airborne particulate matter, etc.

Handling and Use of Equipment

As a complement to the information in the pre-equipping phase, address the following aspects:

- After the equipment supplier's demonstration, the PUE promoter must visit the business to verify that the business activities and equipment are proceeding according to the vendor's instructions.

- If possible, the vendor should be encouraged to examine the equipment installation and verify proper operating conditions.

- Make an unannounced visit to verify that proper operating conditions exist. Equipment

Install equipment in a secure and safe environment, stored in a place of business, rather than in a residence or other location where unauthorized access to the equipment is possible.

modifications should be examined to ascertain whether they are in keeping with manufacturer instructions and the warranty and whether they pose a safety risk for the operator or the equipment.

Worker Hygiene and Safety Conditions

The business must promote good operational practices, provide protective equipment to workers (according to tasks), and handle waste and scrap materials adequately (liquids, solids, and gasses, etc.). Additionally, the employer must provide workers with basic knowledge on accident avoidance strategies, as well as what to do in the event of an accident.

The financing strategy should primarily focus on helping entrepreneurs purchase items necessary to improve the productivity or diversity of their products.

The PUE promoter should therefore take the following steps to confirm worker hygiene and safety:

- Review safety and security measures in areas where raw materials are stored.
- Verify that workers have access to a first aid kit.
- Propose separate handling and storage of dangerous chemical products (due to risk of toxicity or flammability).
- Evaluate the space used for raw materials and other production inputs and investigate potential dangers, and suggest improvements.
- Verify that there are fire extinguishers, tools, sand, water, or other means to suppress a fire (remember the fire triangle: a potential fire = oxygen + combustible material + ignition source).
- Verify that protection equipment exists and is being used by equipment operators (masks, gloves, eye protection, caps, helmets, work shoes/boots).
- Verify the safe handling of waste and scrap materials.
- Confirm that workers understand the risk of dangerous materials and know how to proceed in the event of an accident.

Ask the employer to keep a logbook regarding the PUE promoter's visits. The promoter should sign the book on each visit and record recommendations regarding problems identified during the visit. Additionally, the promoter should keep an independent written record of each technical assistance visit, including the details observed, problems identified and recommendations made.

Financing Strategy

A financing strategy should expand upon the target population's vision concerning the types of financing and financial institutions available. Educate the target population on the basic requirements necessary to qualify for financing. Where a particular financial entity is part of the PUE program, the education should go beyond the basics and provide information on the details of the financial services offered by that development partner.

The financing strategy should primarily focus on helping entrepreneurs purchase items necessary to improve the productivity or diversity of their products. Implementers should target the financing toward elements necessary to achieve sustainability, efficiency, and safety of the product or service that generates income, thus contributing to improved living standards and promoting a more competitive product.

The financing strategy should also take into account the essential characteristics of the target population, including ethnicity, education level, income level, and paying capacity. These considerations are typically incorporated into the strategy implemented by the financial entity chosen to work with the program.

PRODUCTIVE USES PROGRAM IMPLEMENTATION

This section describes the main activities involved in launching a productive uses program.

Coordination with Program Participants

Program participants typically include the PUE program implementing entity, the electric distribution utility (which may be, or eventually become, the implementing entity), the financial institution(s), the electric equipment vendors, and the program beneficiaries (customers). Other potential players are non-governmental organizations (NGOs), national and local governments, and other development entities working in the region.

If the electric distribution utility does not assume leadership of the PUE program, then the program implementing entity (the project's main sponsor, in many cases) must take the lead in coordinating all other players. They must coordinate directly with the electric distribution utility regarding the following key areas:

- Confirm that the electric distribution utility is willing and able to offer reliable and safe electric service to the future program beneficiaries.
- Explore whether the electric distribution utility could provide financing related to the cost of connecting to the electric system.
- Determine whether the electric distribution utility will designate certain personnel or administrative units to work on the program as necessary, depending on the size of the program.

Next, the program implementer must coordinate with the financing institution in these areas:

- Define financing conditions required of program beneficiaries.
- Evaluate whether the financial institution has the necessary liquidity, or whether additional funding sources are required.
- Evaluate whether the financial institution should designate certain personnel to oversee the program and work directly with participants and whether it is necessary to open new offices in the program area.

The implementing entity must also coordinate certain aspects with equipment vendors, such as:

- Determine availability of equipment that program beneficiaries will need and purchase.
- Confirm supplier financing arrangements (if any) and conditions.
- Explore possibilities of opening an office in the project area, if necessary.
- Provide technical assistance and training to program beneficiaries so they can operate and maintain the purchased equipment.

Last, the implementing entity should educate future program beneficiaries concerning the benefits provided by the PUE program as it relates to the electric utility, financing institution, and the equipment providers.

Field work involves accurately identifying existing productive uses in the program area as well as the potential participants in the new PUE program.

Field Work

Field work involves accurately identifying existing productive uses in the program area as well as the potential participants in the new PUE program. Advance planning aids in obtaining the largest quantity of information and verifiable data in the shortest time period, with the smallest investment of resources.

Factors such as the following should be considered in planning field work:

- Geography and distances needed to be covered within the project area

- Range and quantity of productive uses activities to be investigated
- Time required to fill out a survey form
- Number of surveyors required, and the training time necessary
- Travel time required to get from one site to another

To have a realistic idea of the volume and diversity of productive uses activities in the target area, they must be identified and quantified through field work.

Based on this information, develop a work schedule and budget.

Obtaining and Analyzing Historical Data

To obtain the necessary data for the PUE program, begin with existing statistical sources, such as the country's national repository of statistics (known by various names), regional or national government agencies, and NGOs or other entities that work in the project area.

Plan the field work using the historical data obtained, leaving time to accommodate complications that typically arise once work begins. Once the survey team arrives at the field work location, schedules can be adjusted to reflect differences between statistical data and local realities.

In some cases, very complete and reliable data exist, but in other cases, the available data are minimal and potentially useless. In any instance, always proceed with the field work to validate any existing information. If no reliable information exists, the first field work priority is to obtain reliable data. Visiting the area provides information about the topography, infrastructure, and physical barriers that could influence program implementation. It also permits verification of the quantity and type of existing productive uses activities in the area, transportation options and their quality, physical access to the area, the condition of the existing electric system, the distances, and the economic development of the area in general. During the visit, observations of the behavior and character of the inhabitants may provide clues regarding their likely reaction to a PUE program (e.g., they may accept, reject, or remain indifferent to the program).

As an example of what can be accomplished, in the Cochabamba Lower Valley (Bolivia), a team of six surveyors visited 77 communities in 17 days. In that time period, 487 survey forms were filled out, and 586 productive uses activities were identified. That equates to each surveyor filling out an average of five survey forms per day.

Identification of Existing Productive Uses

There are two main groups of productive uses activities: those that are already connected to the electric grid, and those that are not. For those already grid connected, the survey team should identify how those PUE activities could take increased advantage of the electricity they already use. For those not connected to the grid or not yet electrified from any source, the team should investigate the factors motivating the use of alternative or traditional energy sources, and under what conditions users would be willing to utilize grid electricity in their production processes.

The identification of productive uses activities in relation to the electric system is not a simple sorting of electricity users into residential, commercial and industrial categories, as is done with most electrification and utility data. Each of those categories might contain a number of different productive uses. Therefore, more detailed information is needed. As an example, in the Lower Valley of Cochabamba (Bolivia), over 50% of the total productive uses activities were already connected to the electric system and fell within the residential consumer category. To have a realistic idea of the volume and diversity of productive uses activities in the target area, they must be identified and quantified through field work.

The survey team must be knowledgeable about the PUE program and trained to carry out their work efficiently. They must all understand the mission and objectives of the PUE program, and be able to explain them to others. The survey team must be observant, since productive uses activities are not always advertised or identified by company signs, especially in rural areas. For example, the sound of a circular saw in a carpentry shop, or the bright flash in an arc welding shop, or the electronic music of a pub or disco, or the fragrant aroma from a bakery could all serve as clues to seek out potential PUE beneficiaries. Remember that in many developing countries these businesses are often found inside residential homes. The surveyor must pay attention to the entire spectrum of sounds, sights, colors, and smells that a business could emit.

In addition, train the survey team to identify non-electric machinery productive activities in the electrified areas. The project promoters must establish whether it might be financially beneficial for the business to connect to the electric grid and use electric equipment. Examples of non-electrified productive activities include pumps or mills driven by internal combustion engines, as well as many other activities that use diesel, gasoline, natural gas, firewood, waterpower, or simply human energy.

Finally, the program's implementing entity must determine whether it is necessary to carry out a beneficiary analysis in the project area. This analysis provides information regarding how the local inhabitants view the current electric service and the current electric distribution utility. This information is valuable, especially for the electric distribution utility, since challenges in this area must be overcome before the productive uses of electricity program can succeed. Some common issues are poor quality of service, mistrust of meter readings, billing problems, or poor customer treatment by utility employees. The existence of these problems and the lack of will to resolve them can undermine the performance and success of the PUE program.

Information Analysis

Analyze field data carefully. Hasty interpretations could lead to poor decisions causing severe implications for the beneficiary population. If projects are not appropriately sensitive, or are driven solely by financial factors, certain local resources, values, and customs may be altered.

The following are suggested basic elements to use in formulating a productive uses project.

Market Analysis

Prior to implementing a PUE program, the planners should ask themselves some of the same market analysis questions that prospective beneficiaries of such a program would have to ask themselves. They should reflect on the basic question of whether there is a market for the PUE program itself. Beyond that, project promoters should review the questions below to understand how productive use owners will have to analyze the market to decide whether or not to launch a new business or expand an existing one.

An integral analysis begins with knowing the market. This serves as the best starting point for conceiving and implementing the project and lays a solid foundation for its future success. Carefully consider the following questions during market analysis.

Product or Service Questions

- Is the product clearly defined?
- Is it new, or does it already exist?
- Does it meet quality standards?
- What are its strengths, opportunities, weaknesses and threats?
- Are there opportunities to create ancillary products?

- Is it indispensable or easily substituted?
- How will the product be transported to market? What reliable transportation alternatives exist?

Market Questions

- Who are the target clients?
- Where is the target market (local, regional, national, or international)?
- What is the current and potential demand?
- Will demand grow, decrease, or fluctuate seasonally (e.g. with flowers)?
- Does unsatisfied demand exist?
- Who are the competitors, and where are they located?
- How will the quantity produced be determined?
- What is the long-term prospect for the market of these products?

As with the market analysis, it behooves PUE program promoters to put themselves in the place of the productive use owners to think through the technical issues and how such decisions will affect the PUE program overall.

Product Technical Analysis

As with the market analysis, PUE program promoters should put themselves in the place of the productive use owners to think through the technical issues and how such decisions will affect the PUE program overall.

Product technical analysis involves a wide range of issues. Careful analysis of all information is critical, since it can directly affect the sustainability of the business. Key considerations in product technical analysis include:

- Availability of raw materials and source sustainability
- Availability of electric energy, distance, voltage (quality), transformer capacity
- Condition of electric service infrastructure (grid)
- Characteristics of the installed power capacity: existing equipment, power equipment, daily consumption pattern, seasonal pattern
- Manufacturing plant size needed to be competitive, space availability, terrain conditions
- Integration of production processes
- Possibilities to expand installation
- Critical inputs that determine growth or stability of the business
- Experience and availability of a qualified labor force and equipment
- Comparative strengths, weaknesses, opportunities, and threats of competitors
- Technical impediments and foreseeable legal issues

Environmental Analysis

This is yet another area for PUE project planners to consider on two levels, the environmental impact of the program as a whole and the impact of the various productive uses found in the target area. Environmental considerations are increasingly important in evaluating PUE projects. For example, if the PUE program will help construct or finance infrastructure for productive use, each of those construction projects must address environmental issues. It is crucial to determine whether a project environmental impact study is required prior to implementation.

Environmental considerations include:

- Environmental impacts in all phases (raw materials, processing, waste management, etc)

- Permits required
- Regulatory impediments
- Threatened resources (natural, cultural, or social)
- Work environment characteristics
- Mitigation measures and implementation costs
- Environmental financial implications over the life of the project
- Environmental legal framework

Socio-cultural Analysis

Project planners also need to consider cultural and social factors during the design, implementation, and operation of PUE projects. In most rural areas, traditions, customs, ancestral rituals, and deeply entrenched organizational structures exist. These must be respected and included as variables for the design of the productive uses of electricity program. Sociocultural analysis creates a vehicle through which the project can recognize the cultural heritage of indigenous and tribal populations, guaranteed through several international treaties.[1]

Rural populations are usually deeply attached to their ancestral roots. However, they also often suffer from extreme levels of poverty. Social issues emerging from either cultural or ancestral traditions, such as equity in participation (ethnic, creed, and gender), education level, access to services, etc., demand special attention when designing strategies and tactics for a sustainable PUE program.

Financial Analysis

Financial analysis is crucial in determining project feasibility and in making implementation decisions. This analysis should incorporate all previous considerations and assumptions to portray the true costs and the benefits of the project as accurately as possible.

Many projects in rural communities are solely the result of the project promoter's business instincts. Often the rural entrepreneur has little or no comprehension of costs, prices, or concepts such as return on investment.

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Normally, existing business projects have a minimal investment in productive assets, poor documentation, and few or no financial records. This resembles the situation often found in family businesses within the informal sector of the economy, such as a local convenience store.

In businesses where no formal financial documentation exists, management expertise can be established through training on income patterns, seasonal market changes, as well as through managing external financing. Normally, incorporating electricity into the business process within rural businesses creates incremental increases in financial benefits, due to cost savings, quality improvements, and/or increases in productivity.

Projecting the financial viability of an entire PUE program or of an individual productive use is essential to determine whether or not the project or business can attract financing and reach financial sustainability. Determining financial viability is a matter of weighing future cash outlays against projected revenues, so as to define the project's profit or loss.

Promotion of Productive Uses

Resource potential, entrepreneurial intuition, and practical action options can provide insights into what is achievable within a region, if it were possible to rationally combine labor and capital. The challenge for the project visionaries is to promote sound PUE project options that truly apply for the business community of the region.

[1]C169 Indigenous and Tribal Peoples Convention, 1989, of the International Labor Organization.

Identification and Characterization of the Target Population

Electrification has proven to be a collaborative agent that brings about greater utilization of resources in a region, rather than causing industrialization. Experience gained in implementing PUE programs in different latitudes has led NRECA to employ greater sensitivity to specific target population characteristics. These considerations are essential to designing a successful program.

An initial analysis of the target population helps identify variables that will assist in program design, such as levels of education. Such information also helps define the appropriate methods for approaching the target population. This is especially critical in regions that are multi-ethnic and multi-lingual, and where the microclimactic variations within regions can influence a wide range of productive use activities.

Researchers should identify the following target population characteristics:

- Existing services in the area (education service, health service, access to water, communications, etc.)
- Local ethnic groups and languages
- Population dispersion
- Percentages of indigenous populations (for predominant ethnic groups)
- Student population levels and highest level of education available
- Level of illiteracy
- Levels of electricity consumption without a productive uses of electricity program
- Transportation options, road conditions, and distances to other major cities, ports, etc.
- Current productive activities and characteristics
- Degree of electric equipment utilization
- Potential productive use activities in the area
- Types of usable electric equipment available
- Available electricity infrastructure description
- Reliability of the electric service in the area
- Resources availability (human, natural, and financial)
- Development organizations and programs in the area
- Most utilized communication medium
- Community needs that can be met with electricity (water pumping, health services, irrigation, etc.)
- Access to markets to sell finished products and buy raw materials

Communication Media

The communication and promotional media used to inform and educate a community must be designed based on the information about the community. Some variables to keep in mind are:

- Local ethnic groups and common languages
- Percentage of indigenous population
- Illiteracy rate
- Population dispersion
- Access conditions

- Predominant socioeconomic characteristics

Experience has shown that a variety of media work best to approach a community, with human contact as the common denominator. People learn in different ways, and therefore different media of communication must be utilized as well. The mix of different media and communication methods should be sensitive to local characteristics, including language and the literacy rate. Among the methods to consider are the following.

Manuals

Manuals can be used in combination with training instructors, usually including technicians from local organizations, community leaders, financial institution personnel and local authorities. Design the material for simplicity, explaining the PUE program and its different components. It is essential to use the appropriate language or languages, as well as their vocabulary and locally understandable examples, easily grasped by the target population.

Pamphlets

Educational information of this nature should include how to start a business, safety, efficiency, benefits of productive use initiatives, management control, and other subjects. The material should include a variety of visual images and easy-to-read text.

Theater or Dramatization

Theatrical or dramatic performances offer an innovative and practical approach for explaining how a productive uses of electricity program works, what benefits exist, and the steps to follow. Create examples that are compatible with the community's way of life, using the local language, local jokes and nicknames, but without offending or being disrespectful.

This form of communication succeeds when it proceeds with a simple script and easy-to-understand scenes that an audience of diverse ages and educational backgrounds can grasp.

Try to carry out this activity in an appropriate room or hall where the acoustics are conducive to allowing all in attendance to hear. Consider using a sound amplification system where available. For example, in Bolivia puppet theater performances were presented in schools with great success.

Mobile Demonstration Unit

Mobile demonstration units are a highly effective method for communicating productive use information since they tend to arouse the curiosity of the local population about the productive uses program.

This approach requires a vehicle that can carry a variety of electrical equipment and that is suited for rural roads. Select equipment for a community demonstration depending on the type of productive use activities identified in the community during the survey phase.

Demonstrations encourage creative thinking and foster new ideas within the audience. For maximum impact and understanding, however, it is helpful to follow a sequenced set of actions. The following are the most important components of a mobile demonstration:

- The local authorities must officially open the meeting and introduce the participants (electric utility, financing entities, NGOs, suppliers, and other special guests).
- Announce the objective of the demonstration.
- Detail the benefits of electricity for homes and businesses.
- Detail what a safe electric installation entails (show components and functions).
- Describe how to read an electric meter.

Mobile demonstration units are a highly effective method for communicating productive use information since they tend to arouse the curiosity of the local population about the productive uses program.

- Describe how to read an electric bill.

- Describe how to save electricity at home and in the place of business.

- Describe how to use electricity and electric equipment safely.

- Explain the name and function of the various equipment that could be used for local productive use activities.

- Perform a demonstration of the equipment.

- Conduct a raffle as a means to attract a wider audience.

- Announce that at the end of the presentation, a variety of productive use activities will be demonstrated (sharpening of knives or machetes, carpentry activities, wheat grinding, etc.). This will create a further public attraction and method for demonstrating the benefits of the electric equipment.

- Introduce equipment suppliers and financial entity representatives.

An ideal administrative team includes the electric distribution utility, the rural financing entity, NGOs, suppliers of quality equipment, and a project promoter or implementing entity to coordinate the efforts of all players.

NRCECA recommends holding two demonstrations within the same community: a morning session with school-age children and an afternoon session for the entire population.

Videos

Videos are another important medium for illustrating productive uses of electricity. They are usually part of the agenda of a community training session. A video can show PUE projects in other communities, giving people an idea of activities they may want to replicate in their own community.

Videos are a novelty and highly effective as part of a presentation for local authorities, institutions, and other individuals that want to understand the productive use of electricity concept. They are also very popular at the community level, where the use of TV and video forms part of the productive uses program.

Preferably, videos should include simple characters and activities that are easily recognized. On occasion, mainstream video material can be used, such as "The Powerful Atom", a Walt Disney video, which is highly educational, informative, and entertaining, and related to electricity. The promoters may also customize their videos to promote specific programs, using special characters or locations with recognizable names common to the project region.

Photographs

It is helpful to use posters or banners in any group presentation, as well as digital photographs projected through audiovisual equipment. These types of media help explain the program to a varied audience. However, an audiovisual presentation requires access to electricity, so that arrangements must be made for the use of a generator in non-electrified communities.

A photographic presentation can demonstrate examples of successful productive uses, good production practices, as well as errors often encountered in production processes.

Identification of the Program's Administrative and Marketing Team

An ideal administrative team includes the electric distribution utility, the rural financing entity, NGOs, suppliers of quality equipment, and a project promoter or implementing entity to coordinate the efforts of all players. In some cases (as in Bolivia), NRECA hired a company with expertise in marketing and communication for promoting key aspects of its rural electrification projects.

Project promoters must determine whether an adequate marketing entity exists that could assume responsibility for implementing all promotion efforts for the productive uses of electricity program, beginning with the first community contact and extending to all promotion tasks thereafter. The entity might also play an important role in integrating all the players' efforts to promote the program.

Selection of the marketing company should comply with the following profile:

- Conscious of the importance of productive uses of electricity
- Sensitive to conditions and characteristics of the target population
- Knowledgeable about the region and sensitive to the cultural, linguistic, ethnic, and economic situation of that region
- Recognized as a leader on issues related to the productive uses of electricity or in rural area communications
- Understand the entrepreneurial spirit
- Have experience with community development projects, particularly dealing in marketing efforts aimed at increasing social awareness toward specific development objectives
- Have good relations with the local authorities, financial sector organizations, vendors, and other development entities in the area

In Guatemala, Honduras, and Nicaragua, a mixture of NGOs that were responsible for financing, training, and technical assistance, assumed a leadership position for handling the promotional efforts at the community and institutional level for various PUE programs. These NGOs coordinated efforts with the electric distribution utilities (many of which had limited resources) to promote and implement the productive use programs.

NGOs may use their internal staff or subcontract services from other local private companies to promote the PUE program. However, a lead organization must be established to avoid confusion or misunderstanding among the various players.

MONITORING AND EVALUATION OF THE PRODUCTIVE USES PROGRAM

Monitoring and evaluation of productive uses programs begins upon project implementation. Monitoring and evaluation consists of verifying that the PUE program's planned activities are carried out according to the approved project schedule and budget. Identifying variations from planned activities allows for quick adjustments, avoiding adverse effects on program performance.

Monitoring scheduled activities and goals involves verifying time frames for completion of program tasks and comparing the estimates for material use and human resources with the actual program experience. Often the time and resources required to accomplish program tasks differ from initial estimates. Avoid tight scheduling of tasks, to better accommodate unforeseen situations.

Monitoring scheduled activities and goals involves verifying time frames for completion of program tasks and comparing the estimates for material use and human resources with the actual program experience.

A program budget is an integral part of any productive uses of electricity program. It identifies the financial resources necessary to carry out program tasks in a specific time frame. Budget monitoring compares the estimated revenue and expenditures figures with actual amounts. Conduct monthly budget-to-actual comparisons and prepare a written report explaining variances. In addition, prepare quarterly and year-to-date financial reports to identify trends in spending and resources use. This process creates a method to recognize budgeted versus actual differences at an early stage and assists in evaluating the necessity of program adjustments at key intervals.

Specialized software helps systematically monitor program execution. Microsoft's MS Project software is one project management resource.

However, standard spreadsheet software also provides acceptable results.

The post-program evaluation determines whether the objectives and the goals of the PUE program were met and whether the expectations of the players were fulfilled. For example:

- Did the electric cooperative's sales increase because of the program?
- Did the businesses increase revenues because of using electric energy in production processes?
- Did the financial entity reach loan placement targets with acceptable collections?

In addition to evaluating whether the program objectives and goals were met, it is also important to evaluate the quality-of-life improvements and economic enhancement experienced by families in the community.

Impacts on the local economy should also be measured, because PUE programs can generate significant and measurable growth in commerce, industrial production, agricultural production (e.g., the use of water pumps), etc.

Post-program evaluations can be very detailed, depending on the requirements of the program players, and especially if funds for the program were granted through an international donor agency (e.g. USAID or the World Bank). PUE program promoters must keep detailed records of all program benefits and accomplishments throughout program implementation. Keeping up to date with benefits data enables a more efficient evaluation process.

In addition to evaluating whether the program objectives and goals were met, it is also important to evaluate the quality-of-life improvements and economic enhancement experienced by families in the community. Other program aspects to evaluate include equitable participation in the program by all participants, gender-related issues, and environmental impacts. The depth of evaluation of each of these issues depends on the requirements of the entity requesting the evaluation. Many donor agencies and some host governments require reports on environmental impacts or mitigations, as well as data related to equal gender participation in the project. Again, keeping current with such data is advisable.

PRODUCTIVE USES OF ELECTRICITY PROGRAMS: NRECA'S EXPERIENCE

Bolivia – Lower Valley of Cochabamba

When NRECA began the implementation of the USAID-funded *Electrification for Sustainable Development* Project (ESD Project) in Bolivia, it designed a productive uses component for it. This section focuses on the lessons learned from that project.

Objective

The objective of the Lower Valley of Cochabamba PUE project was to promote the productive use of electricity in an area where NRECA worked with the local utility to more optimally use the existing electric grid. The target population primarily included small-scale artisans and merchants, along with a lesser proportion of industry.

Implementation

The program combined the participation of both the electric company and an independent credit agency. NRECA provided the credit agency with seed capital for loans to program beneficiaries.

Businesses that needed to connect to the electric grid obtained financing directly from the electric company, while those interested in acquiring electric equipment received financing through the credit agency. In both cases, program participants bought their equipment and accessories on the open market and at their own convenience.

NRECA made an initial investment of US$112,000, of which US$75,000 was assigned to the loan portfolio and US$37,000 to the credit agency. At the outset of the program, repayment of the loan fund was not anticipated, but due to the success of the program, all funds assigned to the loan portfolio were repaid to NRECA. Subsequently, NRECA later reinvested the repaid funds into a similar initiative with the Rural Electrification Cooperative of Santa Cruz, Bolivia (CRE).

Results

The project goal was 50 productive uses loans. However, 101 loans were actually granted. Recipients ranged from proprietors of businesses with six or seven electric textile machines for garment production, to small commercial stores and manufacturing centers, to individuals selling juices in the local market. Eighty-three shops and businesses benefited, of which 38 used credit to purchase electric machines and the other 45 used credit to purchase raw materials for production. Although increases in energy sales were not significant for the electric company, public relations from the company's involvement in the program were highly positive. Loan placement and collection were successful as well.

Guatemala

Experiences gained in Guatemala changed the paradigm for many organizations working in community development and electrification. This process of organizational change began with NRECA's participation in the Central American Rural Electrification Support Program (CARES), where a productive uses of electricity program was a significant component.

The following are examples of productive uses of electricity programs in Guatemala.

Phase III Rural Electrification Program

From 1987 to 1996, CARES promoted electric use as a tool for business development in rural Guatemalan communities. As part of Guatemala's Rural Electrification Program - Phase III, the Foundation for Economic Development (FUNDAP) administered a productive uses of electricity program, in conjunction with the electric distribution company (National Institute for Electrification, known by its Spanish acronym INDE). The program targeted the western highlands region.

FUNDAP created a strategy to integrate promotion, training, technical assistance, and access to financing as key components of business development. Its approach included promotional material, videos, dramatizations, and mobile unit demonstrations to facilitate financing, technical assistance, and training.

The productive uses program educated families and business owners on the safe, efficient, and productive use of electricity. Businesses gained access to financing, as well as training and technical assistance. Experience in various countries has shown that successful microfinance programs have interest rates that can be as high as 50% per year. Though those rates may sound high, they reflect the cost of providing loans as small as US$100 and all the associated training and follow-up to collect the loans. Note also that these rates are actually very attractive when compared with the exorbitant rates of informal loan sharks. Given these realities, the 30% annual interest rate of FUNDAP did not deter individuals from seeking credit to strengthen their businesses and improve their quality of life.

Program successes included job creation, increased involvement by equipment and raw material suppliers, and increased handicraft and agricultural product exports. Average electric consumption increased from 27kWh/month to 45 kWh/month (including residential and businesses), according to calculations made by the INDE Phase III team.

Although NRECA's support ended in 1996, FUNDAP institutionalized the program, and it continues promoting business development in the rural areas.

Génisis Empresarial / EEGSA (Guatemala Electric Company)

The success of the productive uses program in Guatemala's western highlands led to expanding the program to other regions. In one area, an alliance was created with both a nationally recognized financing entity and an electric distribution company. NRECA was actively involved in this initiative from 1995 to 2006.

Génesis Empresarial, the financing entity, had experience providing loans, technical assistance, and training for small and medium businesses in the urban and peri-urban areas. However, their evaluation criteria for financing proposals did not consider electricity use as a valuable production input.

A partnership developed between Génesis Empresarial and the Empresa Eléctrica de Guatemala Sociedad Anónima (EEGSA) (Guatemala Electric Company) to promote electricity as a means to increase productivity, efficiency, and profitability. The electric company sought to provide incentives for productive use of electricity in rural areas, to improve the paying capacity of rural clients, and to make its investment more profitable by expanding the electric distribution network in rural areas.

These two entities established a productive uses of electricity program with components described in this module. Communication media (e.g. dramatization, videos), technical visits, and training were designed to meet the needs of a local indigenous population. The project used a mobile demonstration unit in community training and promotion. Annual interest rates of 30% covered the cost of an integrated package of services that included the loan, technical assistance, training, a business assessment, and the direct involvement of a credit advisor.

NRECA and EEGSA provided technical training to the Génesis Empresarial financing team, which helped them provide better guidance to business owners and secure loans with less risk. Program representatives made on-site visits to businesses to evaluate installations, perform risk analyses, and assist owners to create specific risk reduction and efficiency improvement plans.

Equipment suppliers (selling sewing machines, carpentry equipment, refrigeration equipment, water pumps, and other items) also played a major role in the success of the program, providing training and technical assistance to buyers and offering competitive prices and equipment warranties.

Génesis Empresarial continues to maintain a productive uses program as a means to strengthen the business sector in rural Guatemala.

El Salvador

With the support of USAID, NRECA began a productive uses of electricity program to complement the National Electric System Reconstruction Program, which built and reconstructed electric distribution lines in El Salvador. The objective was to make rural electrification investments financially attractive and to encourage the use of electricity as a means to improve the productivity and competitiveness of depressed economies in war-torn environments.

From 1987 to 1996, NRECA assisted DISCEL, a government electric distribution entity, by establishing a community selection model linked to the productive potential in communities. NRECA provided concentrated support and human resources training during the reconstruction process.

DISCEL provided leadership in the promotion and training of the productive use of electricity program. DISCEL partnered with various financial entities in each region to provide financial assistance for the program. Banco Nacional de Desarrollo Agrícola and the Fundación para el Desarrollo de El Salvador, were among the entities that took the lead in financing, allocating funds and personnel to coordinate closely with the NRECA and DISCEL team. NRECA provided technical assistance and training throughout the duration of the program, especially in aspects related to safety and energy efficiency.

CONCLUSION

Productive uses of electricity programs are a key element of any rural electrification initiative, rural electric cooperative expansion program, or rural development in general. PUE programs build solid links between an area's electric service provider, financial institutions, governmental authorities, and local business entrepreneurs. For many rural communities, electricity is used mainly for lighting and entertainment, and therefore it is often underutilized as a source of income generation. Local government authorities also tend to have a limited view of electricity promoting its use for such specific purposes as street lighting yet failing to grasp its significance as a key input for business production.

Therefore, the role of the PUE program promoter is multifaceted. He or she must be able to coordinate the efforts and interests of the various players mentioned above, while keeping the big-picture goals of the program in mind. PUE programs must be tailored to the target community. Promoting ill-conceived PUE activities that fail to consider the reality of the community will only frustrate those involved and waste limited resources.

Implementers should employ a multitude of media to promote the PUE program. These can include printed materials (flyers, pamphlets, etc), theatrical presentations, fairs, mobile demonstration units, videos, puppets, and others. Because all individuals learn and retain information in different ways, it is important to utilize more than one medium of communication when promoting the PUE program.

Financing and technical assistance are key components of any PUE program. The PUE promoter must establish links and loan programs with local financial institutions or through the electric distribution utility and equipment suppliers. Through these, program participants can gain access to credit for purchasing electric machinery or funding a connection to the electric grid. Establishing partnerships with financial institutions, both formal and informal, is a key task of the PUE project promoter.

Having a market for the various goods and services produced in the target area is another vital part of a PUE program. All the other components can be in place – reliable electricity, available electric equipment, access to credit, well-educated and capable human resources, cost-effective and efficient production – but there is not sufficient demand for a particular good or service, a productive use initiative will fail.

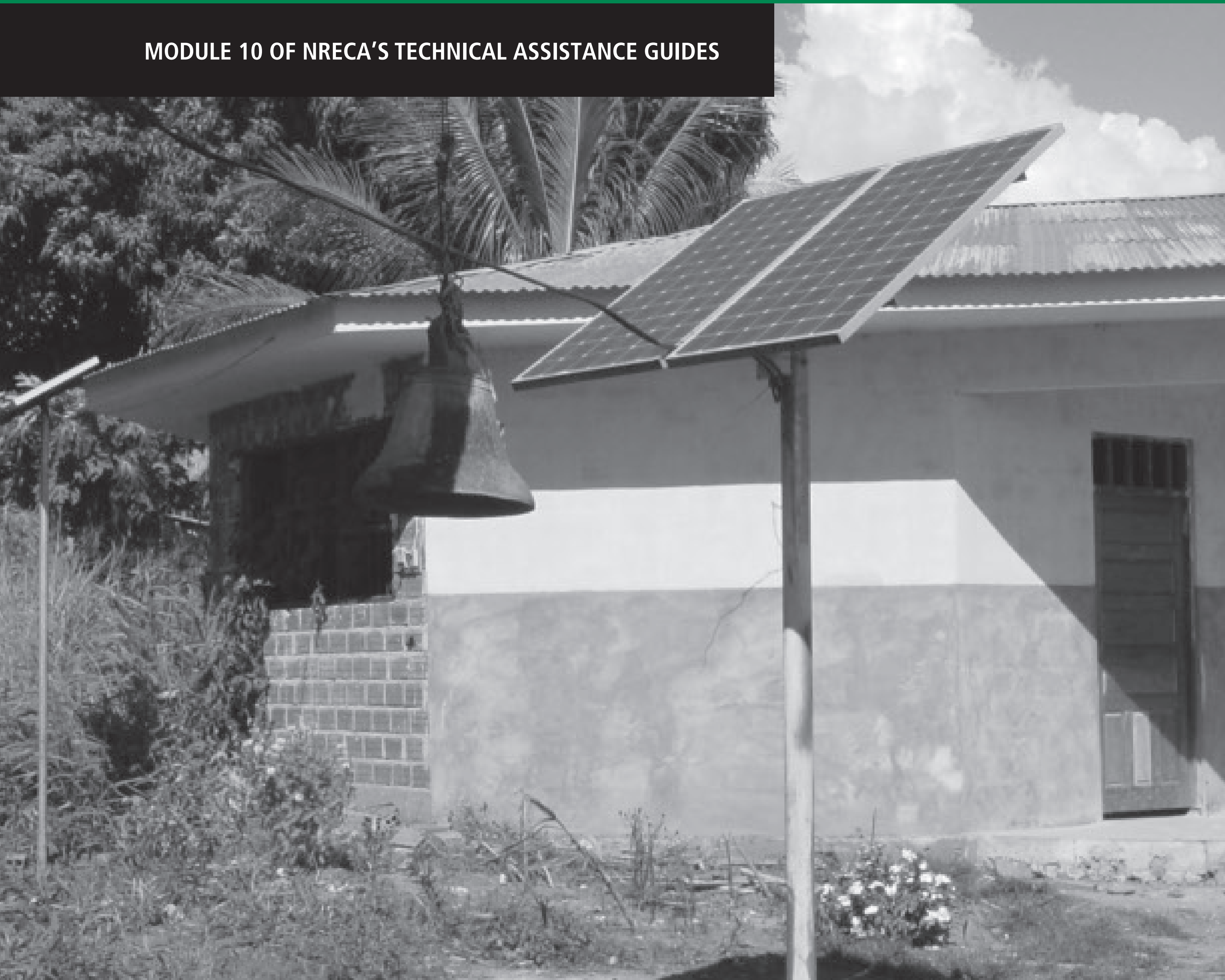
Finally, keep in mind that the PUE program participant is the center of any PUE program. The businesses or individuals that will benefit from the PUE program will be, in the end, the key determinant of project success. It is important to conduct various levels of training for PUE program participants, on both elementary topics of electricity as well as advanced topics of business management. The PUE promoter must also have a close working relationship with the PUE participants, to provide proper guidance as well as proper program monitoring and evaluation.

The use of electricity as a driver of economic growth cannot be overlooked in any community, especially in rural areas. Gathering knowledge about the community, its cultural and social norms, and the different project players and personalities, enhances the PUE program's chance of success. Electricity is not a means to economic growth in and of itself. Without it, however, lasting and sustainable economic growth is not possible.

Gathering knowledge about the community, its cultural and social norms, and the different project players and personalities, enhances the PUE program's chance of success.

Design and Implementation Guidelines for Stand-Alone Solar Photovolatic Systems for Rural Electrification

MODULE 10 OF NRECA'S TECHNICAL ASSISTANCE GUIDES



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EXECUTIVE SUMMARY

This module was developed for institutions and individuals involved in the promotion, design, and implementation of stand-alone solar photovoltaic (solar PV) rural electrification projects. Its concepts and guidelines allow the reader to evaluate a project's technical and financial feasibility, project beneficiaries (i.e. energy demand), and factors affecting solar PV system component performance (e.g. solar irradiance, site geography, energy supply constraints, etc.). Readers will then be able to finalize system design and component selection for optimal system cost and performance. The solar PV design parameters and methodologies presented here also allow project practitioners to understand system operation and maintenance issues, an often overlooked necessity for the proper management of these systems in rural electrification applications.

Renewable energy technologies for remote power supply are particularly appropriate for use in rural areas where grid-based electric service is not financially feasible. In most cases, the implementation of small-scale renewable energy systems occurs in areas of low population density, and low energy demand, where there is nevertheless sufficient income potential to assure the recovery of project costs (capital and/or operating and maintenance costs).

While many technology options can feasibly provide remote energy service to isolated communities, the most practical and lowest cost solutions are normally quite limited. Limiting factors include resource availability, delivered cost of fuel (for conventional fossil-fuel energy systems), and magnitude of demand for energy services. In addition, it is important to take into account operation and maintenance requirements (availability and cost), and the level of technical capacity (required versus available) to support after-installation service for these remote energy systems.

Sustainability of remote renewable energy systems requires the same, if not greater, level of discipline as conventional grid-based energy delivery systems. The following characteristics are essential for assuring project sustainability:

- Engineering design that addresses specific energy needs, while minimizing cost and technological complexity
- Robust institutional structure with dedicated leadership and technical, managerial and operational capacity for project operations and maintenance
- Mobilization of community members to promote a sense of ownership in the project, improve collections efficiency, and reduce maintenance costs for service providers
- Efficient and effective commercial systems to ensure sufficient cost recovery for operations and maintenance costs

In many countries, solar photovoltaic systems are the most promising renewable technology option for delivering modern energy services to rural consumers due to favorable climatic conditions, the energy needs of rural consumers, and their dispersed geographical distribution. Solar photovoltaic systems have been deployed for more than 20 years in a variety of rural, remote applications, with notable success within larger-scale programs. However, there have also been notable failures. Experience demonstrates that these programs require careful planning,

Renewable energy technologies for remote power supply are particularly appropriate for use in rural areas where grid-based electric service is not financially feasible.

extensive and detailed preparation, seamless coordination with communities and local political leadership, and very practical and effective management systems.

The project implementation cycle combines engineering and financial analysis, institutional design and community engagement. This module focuses on all phases of the project implementation and management cycle, including due diligence on the proposed project location, financial and technical analysis, project technical and institutional design, procurement and installation, maintenance, and overall management issues.

In many countries, solar photovoltaic systems are the most promising renewable technology option for delivering modern energy services to rural consumers.

INTRODUCTION

This module serves as a reference for electric cooperatives, technicians, social scientists, and institutions involved in the design and implementation of stand-alone solar PV rural electrification projects. It presents concepts and guidelines that allow the reader to evaluate and make informed decisions concerning project design and feasibility, technology selection, system design, and implementation, as well as to operate, maintain, and manage solar PV systems for rural residential applications.

The module begins with a brief summary of the conceptual framework behind the application of stand-alone solar PV systems in rural electrification. Following the conceptual framework are guidelines on project design, implementation and operation, solar PV design parameters and specifications for system components and, finally, the use and operation of a stand-alone solar PV system and its components.

Because issues related to installation, operation and maintenance practices have challenged the sustainable use of many solar PV projects, this module proposes guidelines to reduce the risks that threaten successful implementation and long-term operation of these projects.

For the most part, the target communities participating in solar PV projects are located in areas distant from grid-based electric service, sometimes in areas quite remote from major population centers. Often, the residents of these communities rely on marginal financial resources, with uncertain incomes and earning potential. As always, finding the means to deliver modern energy services to lower income communities presents specific challenges, requiring deployment of least-cost energy solutions to facilitate the lowest possible recurring costs to project beneficiaries.

CONCEPTUAL FRAMEWORK

The process of increasing access to rural electric service is complicated by the requirement to match the cost of providing the service with the beneficiaries' ability to pay for service. By definition, rural area population density is lower than in urban or peri-urban areas. Moreover, economic opportunities are often more limited than in areas with higher population densities. These two factors usually result in higher costs to deliver commercial energy service and lower revenue potential for energy service providers. The challenge of establishing and sustaining energy services that are appropriately priced, with reasonable reliability, often hinges on the technology selected, and the concurrent amount of energy made available to the community beneficiaries.

Properly designed rural electrification programs take a technology-neutral orientation. While the design of programs should maximize the economic impact of their investments, they must also balance this goal with assuring that the service provided is affordable and the delivery vehicle sustainable. That is, the energy service must meet the needs of the community served while assuring that the cost of operating the energy system can be recovered from the beneficiaries of the service.

Grid-based electric service has historically served as the primary means of delivering rural energy service. With advances made in lower-cost, more reliable renewable energy technologies, and particularly with solar PV panels, it has become possible to offer an alternative to grid electric service. Given the distances and low population density of some rural areas, there are numerous communities that are not, and may never be, practical candidates for the extension of the electric grid. These communities are typically difficult to access, characterized by dispersed housing clusters, often with low income potential and low rates of energy use. Such communities are not likely to receive grid electric service in the near or medium term. Alternate models and modalities of providing electric service are needed to offer an inclusive energy service strategy for these communities.

Considering the lower income levels that most often characterize remote communities, and overlaying the need to assure that projects can achieve financial sustainability, it is necessary to assure that adequate steps are taken to enable target communities to obtain the resources necessary to pay for the cost of service – even if the beneficiaries are expected only to pay for operation and maintenance expenses. This means that an integral part of the project development cycle must include an analysis of the ability and willingness to pay for service and concurrently to estimate the levels of energy consumption and demand of the target population. The project preparation process should also evaluate service provider options and how payments will be collected from the beneficiaries to satisfy operating and maintenance expenses.

Renewable Energy for Rural Electrification

As explained above, renewable energy systems are particularly useful for remote areas that cannot be economically served via grid extension. Such areas have low population density and dispersed housing, resulting in low demand density. Renewable energy systems can be deployed in those areas either as micro systems (such as stand-alone solar systems) or as small or mini-grid distribution systems. To serve these more remote areas, there exists a variety of energy delivery systems, each characterized by fuel type, capital cost, energy delivery capacity, level of expertise required for installation and maintenance, and operating cost. Selection of the most appropriate technology often depends on two primary factors: energy required and total delivered cost of service.

Most rural electrification projects are not attractive financial investments. Even areas that can be economically served with grid electric service often require capital subsidies. Rural areas that can be served only with renewable, off-grid technologies also pose significant challenges to long-term financial viability and generally require a combination of capital subsidies and longer-term support for service provision.

Properly designed rural electrification programs take a technology-neutral orientation.

The design of financing programs to address the divergence between capital cost and ability to pay for service is one of the key barriers to overcome to expand access to renewable energy systems for rural electrification. Developers can meet this challenge by channeling funds through a special project financing facility, by establishing special financing windows in existing infrastructure development or rural development credit facilities, or by creating a special program within an existing rural electrification program management agency. In economically fragile communities, financing issues must be carefully analyzed to find practical solutions that facilitate improved access to electric service. The more accessible and practical the financing mechanism, the less problematic program implementation is likely to be.

Why Choose a Solar Photovoltaic System?

Stand-alone solar photovoltaic systems for residential use represent an increasingly attractive option to meet basic electricity needs of remote communities. The last decade has seen an explosion of solar PV systems installed in a number of large and expanding rural electrification programs.[1] Significant programs have been deployed in Bangladesh, India, East Africa, Morocco, Tunisia, Afghanistan, and China, among other countries.

Use of solar PV systems is most appropriate in those areas where housing density is low, and where energy demand is limited to lighting, communications, and entertainment (usually just radio and television service). These energy needs can be met by the use of what has been called a stand-alone "solar home system" (SHS), a very basic energy supply system comprising a solar PV panel, a charge controller, and a battery to store energy generated by the PV panel. The installed cost of these systems varies according to panel and battery capacity, as well as labor and transport costs. While the costs have decreased marginally in recent years, solar PV systems are still too expensive for all but the most economically advantaged in rural areas. They have and continue to require capital subsidies to achieve notable market penetration.

Use of solar PV systems is most appropriate in those areas where housing density is low, and where energy demand is limited to lighting, communications, and entertainment.

Several important characteristics govern successful implementation of a solar photovoltaic electrification project:

- *Simplicity:* Design of solar PV systems must result in minimum maintenance requirements.

- *Modularity:* Solar PV systems are modular in nature. Considering this, the project design should offer two or more system options to facilitate higher levels of service for those families that may have the means to pay for the increased cost of service.

- *Environmental aspects:* A photovoltaic system does not produce carbon dioxide or other greenhouse gases, and does not otherwise generate environmental pollution. Due to the fact that most solar PV systems employ lead acid batteries, retrieval and recycling programs need to be incorporated in the program to assure that the disposal of batteries does not result in environmental impact.

- *Maintenance:* All energy systems require maintenance, and solar PV systems are no exception. However, maintenance requirements can most often be performed in whole or in part by locally trained technicians. Solar PV systems rarely require highly skilled technicians.

- *Durability:* Solar PV panels have a rated life expectancy of 20 years. Batteries, charge controllers, and lamps have considerably shorter life expectancies. Properly used and maintained flooded batteries have life expectancies of 2-5 years, with longer life expectancy for deep-discharge batteries, and shorter for lead antimony batteries designed for automotive applications.

- *Cost:* As mentioned above, solar PV systems vary in cost according to the size of the panel, battery, wiring/lighting system, and local labor cost. Maintenance and operating costs are normally minimal in comparison to capital costs, assuming that with minimal training, local technicians can provide post-installation service. Solar PV systems require battery maintenance and may require periodic charge controller repair or replacement. Costs can be as low as US$300 for a small, 20 Wp solar PV lighting system, to as much as US$1,000 for a 75 Wp system that provides power for four or more lamps, television, and radio (up to 600 watt-hours of energy per day).

- *Resource availability:* Unlike other renewable energy technologies of broad use (wind, biomass, and hydroelectric), solar energy is relatively homogeneous. Most areas have, at a minimum, four sun-hours of solar radiation per day (where one sun hour is equivalent to 1,000 watt-hours per meter).

[1]Energy Sector Management Assistance Program (ESMAP), *Energy Development Report 2000: Energy Services for the World's Poor* (Washington, D.C.: The World Bank, 2000).

PROJECT DESIGN, IMPLEMENTATION, AND OPERATION GUIDELINES

Successful solar PV project implementation means more than ensuring properly functioning systems during the initial year after installation or during the limited life span of the batteries and charge regulators. The ultimate goal for any solar PV project should be sustainability of energy services over the useful life of the solar PV panels themselves.

Several factors contribute to project sustainability. First and foremost, it is important to specify and procure high-quality system components and to assure that they are properly installed. This requires careful design and management of the project implementation process. This should include a clear and transparent procurement process, verification or pre-qualification of the vendors who sell and install the solar PV systems to ensure that they have the requisite knowledge and skills. It also requires sufficient oversight of the installation contractor by the project's implementing agency or community entity. Finally, and most importantly, there must be sufficient preparation to organize a long-term service provider, either within the community or as an independent contractor, to maintain and repair the solar PV systems over time.

This section addresses the various activities that contribute to project sustainability, beginning with a discussion of the project design and implementation process, including project management and institutional preparation activities. Technical aspects of project implementation are mainly discussed in later sections of the module.

Project Identification and Analysis

Identifying where the solar PV project will be implemented is not complex in itself, but it implies execution of a larger plan of action, the purpose of which is to assist in providing electric service to a specific set of rural communities. The project implementing agency, whether it is an NGO, a faith-based community organization, a donor organization, or a government entity, must develop and evaluate a plan that includes prioritization of communities in specific geographic areas.

There are two principal goals associated with project identification for solar PV projects. First, it is important to take into consideration the means by which projects will be implemented, both during the project preparation and installation phase, as well as in the provision of service phase. Ideally, projects should be defined within a geographic area that can be managed by a local entity or a group of organized community members, such as a cooperative, consumer association, or some other community-based organization. The radius of project influence should thus not exceed the maximum distance the project implementation team can travel in a single workday. Road conditions, modes of transportation, and transportation costs are important factors to consider when evaluating a project's geographic scope.

The ultimate goal for any solar PV project should be sustainability of energy services over the useful life of the solar PV panels themselves.

Another important factor to consider is "minimal project size," or the minimum number of solar PV systems necessary to reach an economy of scale that allows a service provider to cover the cost of serving consumers. Service provider models vary rather radically in legal form, organizational format, and level of expertise. Many solar PV programs involve locally trained technicians, supported by a local administrator. In such cases, routine maintenance expenses are often quite low. While other models exist, NRECA's experience in this field has highlighted the critical importance of training and maintaining local technicians at the project site. Whether the service provider's institutional model is cooperative or private/for-profit, the costs of providing technical and administrative support to projects of this scale are unrealistic without locally available technicians. Regardless of the service delivery model that is employed, the development agency, electric cooperative, or NGO responsible for developing the project must consider the expected operating costs, together with the beneficiaries' ability to pay for service, when determining the required number of beneficiaries and the geographic scope of the project.

The final product of this planning phase involves defining where the project will be located, its geographic radius of influence, the project implementing agency's likely local counterpart agency (community organization, local political leadership, church group, etc.), and the target number of beneficiaries required for project long-term viability.

Many solar PV programs involve locally trained technicians, supported by a local administrator.

Community Organization

Community organization is one of the most critical activities contributing to long-term project sustainability. Community members, as the long-term owners or caretakers of service and assets, need to take ownership in the project itself. (Because many solar PV projects use lease or rental schemes for solar PV systems, the term "owners" is used in a figurative sense here.) Community input is essential for decision making, especially as it pertains to financial contributions to the project and the role and form of local system operation and maintenance entities. If community members do not feel sufficiently engaged in the decision-making process or feel their input is not welcome, significant difficulties in project execution and fee collection are likely to occur later.

There are many approaches to organizing communities and setting up organizations that can effectively interact with rural energy service project proponents and agencies. No form is ideal for all settings. Each social group has its own cultural, ethnic and social characteristics, all of which must be taken into account when making final decisions on which organizational structure to encourage and support. In all cases, there are existing institutional structures that have been used effectively by other development projects, so it is important to survey other development activities as indicators of which organizational and institutional structure might best fit the needs of the project under consideration.

Below are three general steps that have successfully helped establish well-functioning community organizations for solar PV projects:

1. Begin with focus group meetings with community leaders and elders. The purpose of these introductory meetings should be to make sure the community leadership favors supporting the project.

2. Conduct informative meetings with the whole community to explain the goals, objectives and work methods for the solar PV project under consideration. When defining the informational meetings, the team should be sensitive to the level of economic development present in the community, the level of education, and prevailing cultural biases. Seek to understand the development priorities and expectations of community members. Establish with community members that the project is open to all individuals within the community without discrimination.

3. Evaluate the need to form an organized legal entity (for example, a cooperative or consumer association or corporation), and evaluate it's the best form and legal options for the community. Note that while not all projects require legal entities, some work by organizing groups of communities under a common legal framework or umbrella.

If organizers determine the appropriateness of a formal entity, several additional steps are required. The project implementation agency should not assume that the community can successfully complete these steps without intermediation. Communities often require additional support.

Under a community development model often used by NRECA, the following steps are recommended to establish a formal community-based implementation, operations, and management entity, which ultimately acts as the de-facto energy service provider for the community.

1. Conduct a community assembly to explain the organizational process of the formal entity and to propose candidates for an interim board of advisors. This board of advisors will lead the decision-making effort during formation of the formal entity. As part of this process, the community assembly participants should vote to determine the form of their representative community entity.

2. The board of advisors works with the project implementation agency to develop articles of association or incorporation, an organizational plan, and policies and procedures regarding the entity's formal and legal registration.

3. Submit articles of association and other legally required documents to formally register the community entity. Convene a second community assembly to nominate and elect a Board of Directors. Use formal record-keeping to document all key events, decisions, and proceedings.

4. We strongly recommend that the Board of Directors specifically exclude local political leadership and clergy, if possible.

Once organized, the Board of Directors needs to form several working committees to begin to develop the policies, procedures, and organizational tasks for the entity. These committees may include, but will not be limited to an administrative committee, a governance committee, and a technical committee. The committees work with assistance from the project implementation agency to define the functions and scope of services of this newly formed entity, which has now evolved into the community energy service provider. In many cases, the project implementation agency may have sample policies and operating procedures ready for committee review. In this case, these committees participate in training sessions that help them better understand the functions required to effectively provide system maintenance and operating services.

Based upon the understanding of the functionalities that will be provided by the newly formed community energy service provider, the Board of Directors appoints a manager, technicians, and an administrator to oversee the functions of the new entity. All employees or consultants should be trained by the project implementation agency. The defining factor of a successfully operating community energy service provider is whether the entity is able to provide the required maintenance and operating services to assure that its members can continue to operate their solar PV systems over the useful life of the systems. This of course requires the ability to collect sufficient revenues to cover the cost of providing maintenance and repair services for the systems, and to attract technical assistance when necessary from the program implementing agency, or from another source of technical, administrative, or perhaps financial assistance.

Demographic/Willingness to Pay Analysis

The importance of collecting demographic data and data on willingness to pay cannot be overemphasized.

The importance of collecting demographic data and data on willingness to pay cannot be overemphasized. While many, if not all, solar PV projects receive substantial capital subsides, projects that have experienced long-term success have evaluated the capacity of beneficiaries to pay operating costs and have assured that these fees are collected on a routine basis.[2] Efficient bill collection allows the community energy service provider to replace batteries and charge controllers when necessary, and to perform routine and necessary maintenance, including refilling battery cells with distilled

[2] For more information on this process, see Module 6, *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*

water, cleaning the PV panels to assure efficient operation, and troubleshooting outages when they occur.

A household energy survey should be conducted to collect and analyze data on individual household energy usage and costs within the project area. The household energy survey not only illustrates what community members are paying now for energy services, but it also provides information required to determine the appropriate size of the solar PV systems. Keep in mind that community members have varying incomes, and more affluent members may elect to pay for larger systems that provide more energy for lighting and other services.

Solar PV projects most often they require significant subsidies, provided either by a government entity, donor agency, or a non-governmental organization.

A household energy survey or demographic study can also be a vehicle to quantify local preferences, including the type of institution that is preferred, how involved community members want to be in project management and implementation, and what other services they would like energy systems to provide (water supply, energy for community centers, etc.). Programming and conducting these studies should therefore count as an integral part of the project implementation process.

Project Analysis and Feasibility

For most investments, measuring project feasibility is a straightforward process. A financial cash flow analysis uses estimations of capital and operating costs on the one hand, and projected revenues on the other. These are then used to determine net revenues over the expected project life. If the financial results exceed the investment group's required return on investment, the project is feasible. For infrastructure projects that yield economic and social benefits, with only marginal financial revenues, the process is somewhat different in that the costs and benefits of the project can be evaluated against the "target" economic rate of return. In such instances, projects that show economic rates of return that exceed the target economic rate of return are considered viable.

Solar PV projects fall into the latter category, given that most often they require significant subsidies, provided either by a government entity, donor agency, or a non-governmental organization. For solar PV projects financed by government agencies, the economic benefits are normally estimated based upon a regional or national economic evaluation study and quantified in terms of the value of the service per consumer served. This value then determines the maximum government or donor program subsidy provided to the project. If the project can be implemented for an amount not to exceed the maximum subsidy allowed, and if the government office or donor program agrees to provide the required funding, the project is considered viable.

In addition to the factors mentioned above are others that contribute to project sustainability. Projects should not only have to satisfy an economic benefit analysis, they must also demonstrate that the communities and implementing agencies have accomplished, at a minimum, the following:

- Established and organized a local entity that will collect tariffs, manage repairs and maintenance, and maintain communication with sources of technical assistance (a community energy service provider).

- Demonstrate that project beneficiaries have signed service agreements that describe the project implementation agency's responsibilities, identify a modest monthly service fee for system owners, and establish the terms and conditions for project operation.

- Show that administrators and technicians have received adequate training and understand the tasks required to maintain and operate the solar PV systems.

- Show that project beneficiaries have contributed to an initial capital fund (however modest in value) to allow the community energy service provider to pay initial operating costs, including administrator and technician salaries.

Projects that can accomplish these tasks and that demonstrate implementation costs less than or equal to the estimated economic value of the project, will be considered viable and will attract greater financing options.

Procurement Process

Procurement of materials and equipment requires an understanding of the products to be purchased, an understanding of the market from which the material will be purchased, and a well-defined, wisely designed procurement procedure. To assure that procurement results in obtaining high-quality materials at market-competitive prices, the process must be clear and transparent. Its policies must also encourage competition.

Given that most of the components for solar PV systems are made in relatively few countries, including China, Malaysia, India, and others, international bidding is likely necessary, resulting in substantial cost savings. Allowing and encouraging local vendors to participate in the bidding process is necessary and may enhance the project's ability to enforce warranties and guarantee a high quality provision of service.

While each organization is likely to use its own procurement procedure, many development institutions follow quite similar practices. A well-defined procurement process includes the following information components to facilitate qualified responses to a request for quote (RFQ) or request for proposal (RFP):

- *Characteristics of the project area.* These may include location, reference conditions (solar insolation levels, ambient conditions, rainfall data, etc.), community size, types of structures on which panels and system components will be mounted, etc.

- *Evaluation criteria.* This defines the basis for bids to be presented, and the qualities that will be examined to select the most attractive proposal.

- *Description of a bid response format.* These instructions describe how proposals should be presented, including the required data and product information, how to present prices, how to present transportation and insurance data, etc. To facilitate comparative evaluation of bids, it is usually best to include tables to be completed by each bidder to provide characteristics and prices of each item included in the bid.

- *System and component specifications.* This section provides a detailed set of specifications of each system component, including references for equivalent products.

- *Standard contract and payment terms.* While a standard contract is not always included, it may facilitate completion of the procurement process. Advise bidders here of the preferred mode of payment.

To assure that procurement results in obtaining high-quality materials at market-competitive prices, the process must be clear and transparent.

Project Execution

Once materials have been purchased and an installation contractor has been hired (if the bid does not include installation services), the project is ready for installation. Provide installation oversight by hiring and training inspection technicians to ensure that the solar PV systems are properly installed, that the users are trained to use and care for the solar PV systems, and that all components are functioning properly. Ideally, the community technicians responsible for maintenance and repair of the PV systems participate in or directly manage this process, but in any case, be sure to train the technicians responsible for the inspection of newly installed systems.

During the installation phase, also provide further detailed training to the administrator and technicians charged with managing the post-installation services for the project beneficiaries. Multiple training opportunities, even if they are repetitious in nature, help bring about project success.

Should any component failures be noted during the installation phase, a claim should be made with the vendor to replace the defective products, or to otherwise repair them against the product's warranty. As far as possible, test all systems and components to make sure they are functioning according to product specifications.

Service Provision: Project Operation and Sustainability

Successful and sustainable solar PV projects depend on the involvement of all players.

After installation of the solar PV systems, a community energy service provider typically assumes responsibility for all maintenance and repair functions. Given that these entities are largely informal in outlook and practice, a proactive program of monitoring and assistance is necessary. Many projects, and perhaps most projects, proceed on the assumption that consumers will seek and be able to find service providers for routine maintenance and repairs. In some cases, the community may contract with a private firm to carry out this responsibility. However, NRECA's experience has shown that often such service providers are not available. In addition, this option imposes greater costs on the community and the project. Ongoing technical assistance and training to strengthen administrator and technician capacities are essential for long-term project success.

Among many other aids, community energy service providers (or whichever organization is formed to manage the project after implementation) require basic skills to account for and manage financial resources, assist in record keeping, perform routine maintenance activities, and to trouble-shoot technical difficulties as they arise. For training and reference purposes, we recommend that the project implementing agency develop a simple, illustrated instruction book to provide guidance for service technicians. The reference book should emphasize information included in training sessions, provide very practical and easy-to-follow instructions, and provide a list of all tools and materials required for each task described.

The importance of providing periodic training and technical support to the community energy service provider personnel over time cannot be overemphasized. Once solar PV systems are installed, especially for projects in remote areas, it is unrealistic to assume that vendors will send service technicians to diagnose and repair these systems. Local technical support will be essential, so continued training and support to the local personnel serve as the key to long-term sustainability.

Project implementers should therefore include local technicians during the various installation activities of the project, so they can learn on the job and provide basic troubleshooting services to the community energy service provider. Training backup local technicians (one or more, depending on the project size) as well allows for more continuous coverage of maintenance and other issues and reduces overreliance on one individual.

Successful and sustainable solar PV projects depend on the involvement of all players. A community that is knowledgeable and well trained on the benefits, complexities and potential problems of their solar PV systems will ultimately pave the way for project sustainability. Well-guided and appropriate technical calculations and decisions are important. Nevertheless, a well-organized community with several trained technicians will be able to overcome many of the limitations imposed by even the best-designed systems.

SOLAR PV SYSTEM DESIGN PARAMETERS

The first task in designing a stand-alone solar PV system is to evaluate energy consumption of the target community. The energy consumption of prospective households determines the size and characteristics of the solar PV system that satisfies their energy requirements. Dimensioning a solar PV system is a relatively simple process that can be accomplished in several steps. Standardization within solar PV systems is relatively common today, after over 20 years of experience in remote applications. The decision-making process actually has less to do with engineering design than it has to do with matching system component capacities with consumers' ability and willingness to pay for the service. This means that dimensioning solar PV systems is first and foremost a function of understanding energy requirements, and dimensioning the panel, the battery, and ancillary components to meet the energy needs of the consumer. If consumers desire lower-cost energy service, the system capacity can be correspondingly reduced.

Therefore, surveying consumers' needs, preferences, and economic capacity is important. Data that is required to appropriately size a solar PV system for a household include:

- Historic energy consumption patterns, by type of service, use and energy supply (examples: lighting via candles or kerosene lamps, heating via firewood, cooking via charcoal or propane stoves, etc)
- Ability and willingness to pay for energy service[3]
- Potential to use electricity to increase income generation capacity through increased production[4]
- Confirmation of solar energy radiation
- Capacity for local technicians to manage installation and maintenance requirements
- Availability of locally procured system replacement parts

[3]For more information on this process, see Module 6: *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*
[4]For more information, see Module 9: *Productive Uses of Electricity.*

Energy Balance

As mentioned above, the most critical factor in determining system capacity and design configuration is the evaluation of community energy requirements, to determine whether the calculated energy demand can be satisfied with solar photovoltaic energy or other renewable resources. If a household's energy requirements are limited to lighting and other low-energy consumptive uses, such as television and radio, solar PV systems can be an ideal solution. Dimensioning the system becomes a simple exercise of selecting a solar PV panel size, determining the desired number of days of autonomy (days without sunlight), and selecting components accordingly. Standard design methodology requires that the system engineer base the panel and battery size on the solar insolation level for the month of minimum radiation, together with expected consumption during this time of year. (Insolation is a measure of solar radiation energy received on a given surface area in a given time.)

The first task in designing a stand-alone solar PV system is to evaluate energy consumption of the target community.

Estimating the Energy Supply

Approximate values for solar insolation are readily available for most areas throughout the world. Solar radiation maps are widely available from many institutions via internet databases. More precise levels of radiation can be acquired through national or international meteorological databases, such as the U.S. National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center.

National atmospheric databases normally contain decades of weather data, with data most often presented for discrete years, and in the form of statistical averages. In the Dominican Republic the agency that collects, processes, and distributes this data is the National Meteorology Institute and the Institute for Hydraulic Resources. In Guatemala, the institute responsible for data collection and dissemination is the Institute for Seismology, Volcanology, and Meteorology.

National atmospheric databases normally contain decades of weather data, with data most often presented for discrete years, and in the form of statistical averages.

Three complementary sources indicators provide information that can be useful in determining whether there is sufficient solar insolation for the use of solar PV systems.

Vegetation

Certain plants are indicators of the intensity of solar insolation due to their preference for environments with high degrees of sunlight. For example, many species of the cactaceae family (of which the cactus is a member, native to the Americas) and the leguminosae family (also known as the fabacaea, commonly known as the legume or bean family) prefer abundant sunlight. Consider also that communities where vegetation grows lower to the ground are preferable for solar PV systems because such vegetation naturally tends to produce less shade. Keep in mind that the more shaded an area is, with vegetation or otherwise, the less solar insolation it has, and therefore the less useful a solar PV system becomes.

Topography

Topography is not critical to dimensioning or implementing solar PV systems for rural electrification, except for areas with pronounced topographic changes, which can cause shading effects, depending on the location and orientation of the community within the area. Topography also can be useful information for estimating difficulties in deployment or installation of the program activities. Topographic data are commonly available in many countries through national cartographic institutes, and may also be available through international agencies, such as the United Nations Development Program (UNDP).

Climate

Weather data, including prolonged periods of cloud cover, are extremely important for final project design. Because national data sets are often not based on data derived from weather stations, data provided by national weather or climate centers can often lack precision, especially for estimating battery capacity (days of system autonomy).

It is always useful to consult with farmers and technicians in the area, or those tradesmen and business people whose activities depend upon the frequency and/or duration of rain. These local sources can provide information concerning cloudiness, relative humidity, fog, wind, and other elements that can affect the efficacy of a solar PV system's operation.

Estimating Energy Demand

Estimating energy demand involves estimating average daily and monthly energy consumption for the target project population. The most common tool used to determine energy consumption is a household energy survey. As was previously mentioned, this tool collects basic demographic information from randomly selected households, statistically evaluates consumption trends, and determines consumer ability to pay for energy service (electric and non-electric). Some of the most important data collected in a household energy survey include the following:

- Fuels, appliances, and fuel consumption used for lighting purposes. The analyst must attempt to tabulate all forms of lighting that may be employed, including candles, flashlights, kerosene lamps, gas lamps, and electric lights. The survey ascertains fuel consumption for each individual technology, together with prices and average monthly cost.

- Fuels, appliances, and fuel consumption used for cooking. If more than one fuel is used for cooking (a combination of wood and charcoal for example), quantities and prices are estimated for each. Liquified petroleum gas (LPG) and kerosene may also be used in combination with other fuels.

- Fuels, appliances, and fuel consumption for other uses of electricity. This could include either a car battery used for powering larger portable radios, or small gasoline or diesel generators to power televisions or refrigerators. LPG used to fuel any other appliance must also be listed. A key example is an LPG-powered refrigerator. The analyst must note the name-plate capacity (in watts) of each appliance, its respective generating unit (e.g. a battery or a generator), the estimated average use per day or week, and any comments from the surveyed household on possible changes in consumption. For personal generators, note the type of fuel used, the daily/weekly/monthly consumption of fuel and its associated cost, its name-plate capacity (in kVA and kW). Also list the appliances powered by the generator. For larger batteries, note the capacity of the battery(ies) used, the daily/weekly/duration of their use (and for what appliance), as well as the cost and frequency of recharging.

- For households surveyed that have access to electric service, develop a table of the type and number of electric appliances. These might include a radio, television, refrigerator, fans, etc. This table would include the name plate capacity (in watts) of each appliance, the estimated average use per day or week, and any comments from the surveyed household on possible changes in consumption. Ask for past electric service bills (typically three are sufficient), keeping in mind that energy consumption varies depending on the seasons.

From the survey forms, tabulate the data into a database, then statistically analyze the data to provide energy consumption estimates for the project area, as well as estimates for the average individual consumer. The analyzed dataset will also yield willingness and ability to pay estimates, which in turn becomes input for evaluating service provider models for the project area.[5]

[5]For more detailed information on willingness to pay, see Module 6, *Consumer Willingness to Pay and Economic Benefit Analysis of Rural Electrification Projects.*

System Components

The principal components of a solar PV system include the solar PV panel, the battery, the charge controller, lamps, outlets, and connecting/mounting hardware. The component capacities are dimensioned to satisfy the consumer demand that was determined from the household energy survey.

TECHNICAL SPECIFICATIONS FOR STAND-ALONE SOLAR PV SYSTEMS

The principal components of a solar PV system include the solar PV panel, the battery, the charge controller, lamps, outlets, and connecting/mounting hardware.

Presented below are the suggested minimum specifications for the principal components of solar PV systems for rural electrification applications. These specifications promote longevity of service and reliable operation of the solar PV system.

Photovoltaic Module

The solar photovoltaic module consists of both the module and a connection box terminal. The photovoltaic cells can employ mono-crystalline, polycrystalline, or non-crystalline/amorphous silicon. Mono-crystalline, or single crystalline, silicone modules are primarily used in space related PV applications due to their high efficiency; however this is matched by their high manufacturing costs. In general, polycrystalline modules are most often preferred for rural and urban PV systems. As compared with non-crystal/amorphous crystalline modules, polycrystalline modules have a higher stability of the substrate, and therefore relatively stable electric output over the useful life of the models. Amorphous modules are cheap but inefficient, while single crystalline silicone modules are more efficient but costly.

The module frame, which protects the solar panel and connects it to the outside of the house or a pole, should be aluminum and of sufficient thickness to withstand expected wind stress for the project area. The peak nominal power value for each module must be clearly indicated on the module itself. The most important specification of panel output is the rated peak watts (Wp) under maximum solar insolation (1 kW-square meter).

All solar PV modules, whether amorphous or polycrystalline, must have a UL (Underwriter Laboratory) certification and recent applicable panel quality tests. The panel quality test should be certified by the International Electro-technical Commission (IEC), the U.S. Jet Propulsion Laboratory or the ISPRA (Community Research Center in Italy).

NRECA recommends open-cell, flooded lead-antimony and deep-cycle type batteries for solar PV systems for rural electrification applications.

Warranty information for the module must be clearly specified on the warranty certificates provided with the product. The manufacturer warranty must cover defects in fabrication and/or assembly. All panels should be warranted to produce no less than 90% of nominal power during the first 10 years of operation.

In addition to warranty information, manufacturers and vendors should provide current-voltage curves that illustrate the module output under standard photovoltaic cell testing conditions. Standard test conditions are at a solar radiation intensity of 1000 W/m2 (one standard sun), with a cell temperature of 25°C.

Battery

NRECA recommends open-cell, flooded lead-antimony and deep-cycle type batteries for solar PV systems for rural electrification applications. Although in many developing countries new or used 12-volt car batteries are often used with solar PV systems because they are cheaper and easier to find and replace, NRECA does not recommend them due to the short life expectancy of the former and the discharge characteristics of the latter.

Manufacturers and/or vendors should present performance data and physical characteristics of the batteries supplied. The data should include a description of the technical and mechanical characteristics of the battery; a charge and discharge curve for C/20 and C/8 rates of discharge; estimated battery life cycles at 50% depth of discharge; and the length and terms of the warranty. (C/20 refers to a current draw at which the battery will become fully discharged within 20 hours; similarly, C/8 is the rate of discharge corresponding to full discharge within 8 hours.)

Charge Controller

The charge controller, or regulator, regulates charge and discharge current from the batteries, besides connecting the solar PV panel and appliance or lighting loads to the battery. The charge controller protects the battery from over-charging and excess discharge by connecting the battery to the solar array when the voltage level drops below a prescribed level, and disconnecting the battery when the voltage reaches a maximum level. The connect and disconnect set points are distinct for each battery type, so it is very important to make sure that regulators are specified to work in tandem with a specific battery. Charge regulators are rated by maximum current-carrying capacity that is normally specified as 125-150% of the maximum expected load for the solar PV system.

Modern regulators are controlled by microprocessors and are pre-programmed to provide temperature compensation to regulate the charging algorithm to adjust itself with changing ambient conditions. Modern regulators also employ a charging pattern known as pulse width modulation to make the battery charging cycle more efficient. The following characteristics should be specified when purchasing charge regulators:

- The charge controller must protect against:
  - Short circuits in the charge terminal
  - Transient waves of voltage induced by atmospheric discharges (lightning)

- Polarity reversal in the module's terminal

- Temperature compensation should adjust the charging current to the battery against varying ambient conditions.

- Charge algorithm should employ Pulse Width Modulation (PWM).

- Set points for disconnection and reconnection of the battery charging cycle (for lead antimony batteries) should be as follows:

  - High voltage disconnection (HVD) at 14.2 V +/- 0.2V

  - Low voltage disconnection (LVD) at 11.5V +/- 0.2V

  - Low voltage reconnection (LVR) at 12.5V +/- 0.2V

- The regulator should have easy-to-read indicators illustrating the battery's state of charge, including a light that shows when the battery is fully charged and a series of lights to indicate the level of charge.

- The regulator must have a frame resistant to rust, with an encapsulated IP index of 5.4 (resistant to dust and water spills).

Lighting and Lamps

Normally, stand-alone solar PV systems produce very little electric energy in comparison with conventional fossil-fuel based portable power systems. For this reason, energy conversion devices, including lamps, must employ the most efficient technology available. Lamps used in conjunction with solar PV systems should be fluorescent-type tubes or compact fluorescent bulbs.

A typical fluorescent lamp is composed of the tube or bulb, electronic ballast, a frame, and mounting accessories. Compact fluorescent bulbs integrate the bulb and ballast in a single, enclosed bulb that can be fitted into a standard light fixture, either overhead or mounted in a table lamp. These bulbs are very convenient, and with mass production, they are becoming more competitively priced with tube-type fluorescent lamps. NRECA recommends the following lamp characteristics:

- Nominal voltage of operation should be 12 V DC.

- Recommended nominal capacity can vary from 7 to 20W, depending upon illumination requirements.

- To avoid the temptation to use incandescent bulbs in conjunction with solar PV systems, we recommend against use of the common screw or the bayonet-type inserts. We recommend lamps that require direct connection via a wiring fixture.

- Use lamps that are protected against polarity reversal.

- The color index of the bulbs (CCT) should exceed 3000K.

- The frame of the lamp should include a white reflector to maximize illumination. Use of diffusers is discouraged.

- Protect the lamps against dust and insects by mounting them in sealed enclosures.

- Purchase each lamp in conjunction with the appropriate ceiling or wall mounting fixture and hardware.

Lamps used in conjunction with solar PV systems should be fluorescent-type tubes or compact fluorescent bulbs.

DIMENSIONING SOLAR PV SYSTEM COMPONENTS

Solar PV systems are dimensioned in distinct sizes, based upon the daily energy consumption determined through the household energy survey, the number of days of autonomy required, and the panel capacity, measured in peak watts (Wp). Since panel and battery manufacturers produce products with distinct characteristics, systems are dimensioned to satisfy a specific operating range of energy consumption in a way that is consistent with the modules' operating parameters.

While system efficiency and performance are important characteristics, durability and reliability are higher priorities.

While system efficiency and performance are important characteristics, durability and reliability are higher priorities. With this in mind, adhere to the following principles should be adhered to when defining system characteristics:

- *Simplicity*. Commonly, more complex systems require a higher degree of maintenance and technical support. Avoid system complexity, unless there are overriding reasons in support of it.
- *Equipment performance data*. Solar PV panels should include third party performance certificates. Batteries, charge controllers, and lamp products should conform to international safety and performance specifications.
- *Efficiency*. Products with demonstratively higher performance efficiency will result in financial savings and greater net energy supply. However, higher efficiency products must be balanced against the cost of maintaining advanced electronic components.

Dimensioning Solar PV Panels

Each step of the design process requires a specific procedure to ensure that the energy generated and stored in the battery will meet the energy needs of the target beneficiaries. For solar PV systems, normally the energy service provided will be sufficient for lighting purposes for powering a small television set and/or a radio.

Most stand-alone solar PV home systems are designed around a specific lighting load, such as two or three lamps, rated at 11, 15, or 18 watts. In the calculations below, we assume that the solar PV system will provide electricity for three 11-watt lamps to be used for three hours per night, as well as a small television set to be used for three hours per day. Other combinations of lights and television usage could be used by the design engineer to meet user preferences.

The first step in this process is to calculate the specific system load, or the total amount of energy drawn by the electrical devices connected to the PV system. Calculating the system's load will allows the system designer to properly dimension the panels, batteries, and other components, as well as estimate the project's cost. Estimating loads, especially in non-electrified areas, can be at times difficult but it is normally a relatively simple process.

Design the system for the worst-case scenario while at the same time remembering to account for consumers' ability and willingness to pay for the system. In some cases, a consumer's limited ability to pay for the service or system affects the final design of the system, usually limiting the system's loads to keep equipment capital costs as low as possible.

In most rural electrification projects using renewable or isolated generation systems, the designer must first determine whether the system will use direct current (DC) or alternating current (AC). Most solar PV systems use a DC current electrical wiring system, especially in isolated rural areas. DC systems allow for easier storage of electrical energy (in batteries), are less sophisticated, and cost less overall. AC systems, on the other hand, are normally used when energy must be transmitted or distributed over larger distances, to use specific household or consumer appliances, for connection to the electric grid, and/or for convenience.[6] Therefore, the example to follow, like most solar PV projects, uses a DC system. The lighting apparatus, batteries and

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[6]Inversin, Allen R. *Micro-hydropower Sourcebook: A Practical Guide to Design and Implementation in Developing Countries*. London: ITDG Publishing, 1986.

appliances will also be designed and selected according to a DC system.

Assuming the selection of a DC solar PV system, the next step requires the designer to determine the operating voltage of the system. Most DC systems run in increments of 12 volts (V) from 12 – 48 V DC. For DC systems, this selection is made based upon the requirements of the largest load. A 12 V DC system can be used in most solar PV systems smaller than 1 kilowatt.[7] As an aid to this process, the designer may calculate the total system power demand, in watts or kilowatts. Rural solar PV projects typically are 12 V DC systems.

Next, the designer must determine the type, capacity, quantity, and usage of the power load even though the load might not yet exist. Therefore, the designer must work with the community to determine what loads are appropriate, based upon the project's cost. An example of this information is presented below in Tables 1 and 2. In our example, the system load characteristics are the following:

- Three 11-watt lamps, used for 3 hours per day
- One 20-watt television, used for 3 hours per day

Note that in the example cited above, all three lamps are identical (in type and capacity). If different wattage lamps are used, the designer must calculate separate power demands for each.

The next step is to multiply watts (W) times hours of use and quantity, for each identical load to arrive at daily consumption in watt-hours. Using the lamps example, 3 (quantity) multiplied by 11 (watts capacity) multiplied by 3 (hours of daily use), equates to 99 watt-hours daily consumption. Using the same formula, we calculate 60 watt-hours as the total daily consumption of the TV.

The designer then multiplies the daily watt-hours load for each appliance by an efficiency factor (which can be estimated at 1.5 for most small-scale stand-alone solar PV systems) to obtain daily adjusted watt-hours use. The efficiency factor accounts for several factors, including wiring and interconnection losses, all system efficiencies, and battery charge and discharge cycles.[8] Adding the daily adjusted watt-hours usages for each appliance yields the total adjusted watt-hours use for the system. This figure is used to dimension the solar PV array. Table 1 shows a calculation for the above-mentioned process, in which a total of 238.5 adjusted watt-hours load was calculated for the system as a whole.

The designer must note whether appliance use will vary greatly depending on the seasons or months of the year. System load calculations may be required for each different season (summer vs. winter, for example) depending on the size of the

The designer must determine the type, capacity, quantity, and usage of the power load even though the load might not yet exist.

[7]*Sandia National Laboratories. Stand-Alone Photovoltaic Systems a Handbook of Recommended Design Practices.* NY: Ntis, 1995.

[8]Sandia National Laboratories. "Recommended Design Practices." Photovoltaics Main Page. 8 Jan. 2009 <http://photovoltaics.sandia.gov/docs/Recommended%20Design%20Practices.htm>.

Table 1. Example of calculating system loads

Appliance	Quantity		Watt Capacity (per unit) (W)		Usage (hours per day)		Daily Watt-hours load		Efficiency (decimal)		Daily Adjusted Watt-hour load	Operating Voltage (DC	Power Conversion Efficiency	Daily Amp-hour load (AH/Day)
Lamps	3	x	11	x	3	=	99	x	1.5	=	148.5	12	1.0	8.25
TV	1	x	20	x	3	=	60	x	1.5	=	90.0	12	1.0	5.0
TOTAL							159				238.5	12	1.0	13.3

system. In most small stand-alone PV systems, when electricity is used to power lighting and an entertainment source only, this dual calculation is not necessary. Nevertheless, the designer should still design a system for the worst-case scenario, depending on the cost.

After calculating the daily load on the system, the designer next dimensions the solar array, which consists of a number of solar modules connected together in series or parallel. This step calculates the number of modules required. It actually involves three tasks that must be accomplished but in no particular order. The most important of these tasks for the designer is calculating the average hours of sunlight per day available in the area. For areas where solar resource data is available, this variable is usually measured in energy per surface area per day (or $kWh/m^2/day$). Keep in mind that this variable changes with the seasons as well as with the community's distance from the. The farther away the community is from the equator, the more this variable fluctuates during the year. Another important variable in this calculation is the relative cloudiness of the community. Since macro-level national weather data often lacks the level of precision required, it is important to discuss climate patterns (rainy season, humidity, etc.) with local community members. On average, most sites allow for 4-5 hours of sunlight per day.

As part of calculating the hours of sunlight per day, designers need to determine the angle of tilt of the solar PV array. For stand-alone solar PV systems, the angle of tilt usually ranges from -15° to +15°. Larger systems do at times employ bi-directional tilting and tracking, but these concepts are highly uncommon in small-scale solar PV systems and therefore are not discussed in this module. The angle of tilt selected is a variable of the community's latitudinal position on the globe. Designers should consult other practitioners in the country, or the relevant government agency, to ascertain the proper degree of tilt for the latitude of a certain community.

If no hours of daily sunlight data are available for a particular site, the analyst must conduct several field tests to obtain the data. The system designer must manually calculate this variable by measuring the hours of peak sunlight – the number of hours per day during which solar irradiance averages 1000 W / m^2. Keep in mind that the hours of sunlight may change significantly depending on the community's latitude and the season.

The example below uses the estimate of 4.5 hours of sunlight being available per day on average. Designers based this on national climatic data as well as consultations with community members.

Next, to dimension the solar PV array, the designer divides the daily adjusted watt-hour load by the daily average hours of sunlight. In Table 2, this calculation results in a required array wattage of 53 watts.

Following this, the designer and project team must survey the market (local, national, and perhaps international) for solar PV modules that would best fit their needs. This research can also be conducted much earlier in the design phase. The selection of a PV module depends on a variety

Table 2. Example of solar PV array dimensioning

Daily Adjusted Watt-hour use		Daily hours of sunlight		Required Array Wattage (W)		Solar Module Wattage Selected (W)	Quantity Desired
238.5	/	4.5	=	53.0		60	1

of factors, of which critical importance should be placed on quality, market availability, local availability of replacement parts and technical support, valid warranties on modules and parts, as well as UL (Underwriter Laboratory) certification and recent applicable panel quality tests.

In selecting a PV module, the team must look at both electrical capacities and cost. For example, in Table 2, a 53 watt array is needed. However, the designer will probably not find a specific solar PV module rated for 53 watts. Always round up, not down. In our example, the module selected was rated for 60 watts, resulting in only one module being required to fulfill the system's load demands. If a 60-watt panel were not available, the design team would have to consider other options, including using two smaller wattage modules or using a single module of larger watt capacity.

In most developing country solar PV markets, the variables of cost and quality play a key role. Often the lowest-quality modules are the cheapest, and therefore consumers are often drawn to them as the better option. Poor-quality products are much more expensive in the long-term, due to the high and reoccurring cost of maintenance or replacement.

Dimensioning the Batteries

Batteries are the most problematic component of a solar PV system, as well as the component most likely to fail if improperly sized to meet the loading conditions imposed by its users. Lead acid batteries last much longer if they are minimally discharged to no more than 20% of their rated capacity on a daily basis, while deep discharge batteries can be drawn down to 80% of their capacity, with only 20% of the charge remaining. However, they last longer if they are operated in so-called "float mode," at the upper 20% of their total capacity.

In evaluating battery options, it is important to dimension battery size by five times the daily expected energy requirement, if possible. This requires that the design engineer evaluate the daily energy demand and the number of days of autonomy that are desired, then assume a low charge-discharge efficiency for the battery cycle. The round-trip (charge-discharge) efficiency is normally approximated at 50%. This means that only 50% of the energy that goes into the battery is ultimately available for use to serve the load.

First, the analyst must calculate a daily adjusted watt-hour load on the battery by assuming a total round-trip battery efficiency of 50%. Therefore, the daily watt-hour load is multiplied by 1.5. In the sample calculation in Table 3, this gives a daily adjusted watt-hour load of 238.5. The adjusted daily load is then multiplied by 5, so that the battery or batteries ensure a 20% daily drawdown, giving a battery design load of 1192.5 watt-hours. The daily discharge factor prevents the batteries from being deep-cycled daily (drawn down to the lower 20% of their capacity), leaving this duty for only occasional necessity. Then to calculate the required battery amp-hours, the designer divides the battery design load by the system's nominal voltage (12 Volts DC in this case), giving a required battery amp-hours figure of 99.4 AH/day.

Batteries are the most problematic component of a solar PV system, as well as the component most likely to fail if improperly sized to meet the loading conditions imposed by its users.

Table 3. Sample battery sizing calculation

Daily Watt-hour load		Battery Efficiency Factor		Daily Adjusted Watt-hour load		Daily Discharge Factor (for daily discharge of 20%)		Battery Design Load (watt-hour)		Nominal System Voltage (V)		Required Battery Amp-hours (AH)		Amp-hours of Battery Selected (AH)	Number of Batteries Required
159	x	1.5	=	238.5	x	5	=	1192.5	/	12	=	99.375		105	1

Finally, the project team must again survey the market for available and appropriate batteries. The selection of a battery greatly depends on market availability and price. Again, remember that the listed daily amp-hours of the battery should be more that what is required by the system's loads and conditions. Dividing the amp-hours required, by the amp-hours listed on the battery selected results in a figure for the number of batteries needed. Always select batteries of high quality. While costs should be kept in mind, choosing a higher quality product can result in cost savings by avoiding expensive repairs, having to buy replacement parts, or even needing to replace the battery. As a general rule of thumb for PV systems, the bigger and heavier the battery available, the better.

Charge controllers must also match the characteristics of the battery that is selected for the solar PV system.

When selecting a battery, also consider the availability of compatible charge controllers. A discussion of charge controllers follows below. Avoid automobile batteries if possible. Automobile batteries quickly become useless when integrated into a solar PV system. Solar PV systems charge their complementary batteries slowly over long time periods, while automobile batteries are designed to be quickly recharged, and they produce only a high current in a short time span. Finally, keep in mind that even PV batteries do not last as long as the useful life of the PV array (20-25 years in most cases). Commonly, deep-cycle batteries have a useful life of 5-10 years.

Balance of System Components

The following practical criteria must be considered in the dimensioning of the balance of system components.

Charge Controller

Select the charge controller based on the expected peak load amp capacity of the solar PV system, as well as the characteristics of the battery. Designers often select charge controllers by evaluating the expected peak current and multiplying this current by a safety factor of 1.25-1.5.

Charge controllers must also match the characteristics of the battery that is selected for the solar PV system. Lead antimony batteries have distinct characteristics from lead calcium batteries; the high voltage disconnect and low voltage reconnect points are different from one another. Therefore, the type of battery (lead acid versus lead antimony) should be evaluated prior to selection of the charge controller. NRECA recommends the use of open-cell, flooded lead-antimony and deep-cycle type batteries for solar PV systems in rural electrification applications.

Lighting (Lamps)

Lamps are available in a variety of sizes to suit many different applications. Lamp rating normally goes by the luminosity that is required for the room to be lit. Small bedrooms may require compact fluorescent lamps of 7-9 watts, while larger dining and living areas may require multiple lamps with a capacity of 18-20 watts.

In addition to determining the size of the lamps used, consider costs and market availability. Avoid lamps that must be specially imported as they are not practical in the longer term. Incandescent lamps are also not suitable for solar PV systems. In most cases, compact fluorescent light bulbs (CFLs) are used in place of incandescents due to their higher efficiency. Again, pay close attention to the quality of the CFL or lamp selected. Where less light may be needed, light-emitting diode (LED) lamps are a possibility.

Wiring

In selecting internal wiring (also known as conductor) size, the goal is to minimize energy loss and voltage drop. Voltage drop is an important for conductor size if loads are located far away from the battery and voltage regulator. Given that solar PV systems normally operate at 12-24 volts DC, line loss and voltage drop can be significant unless caution is used in selecting conductor size.

In all cases, we recommend applying the national electric code when selecting wire size for reasons of safety and system performance. If there is no published national electric code, NRECA recommends use of the National Electric Code of the U.S.

Conductors selected should meet the worst-case scenario conditions of the system and its environment. Consider also whether the conductor will be installed in direct sunlight, buried underground, or both. In addition, analyze the ambient and operating temperature of the conductor. It is often best to work with the solar PV array vendor to select the most appropriate conductor type for the system, keeping in mind its design and layout.

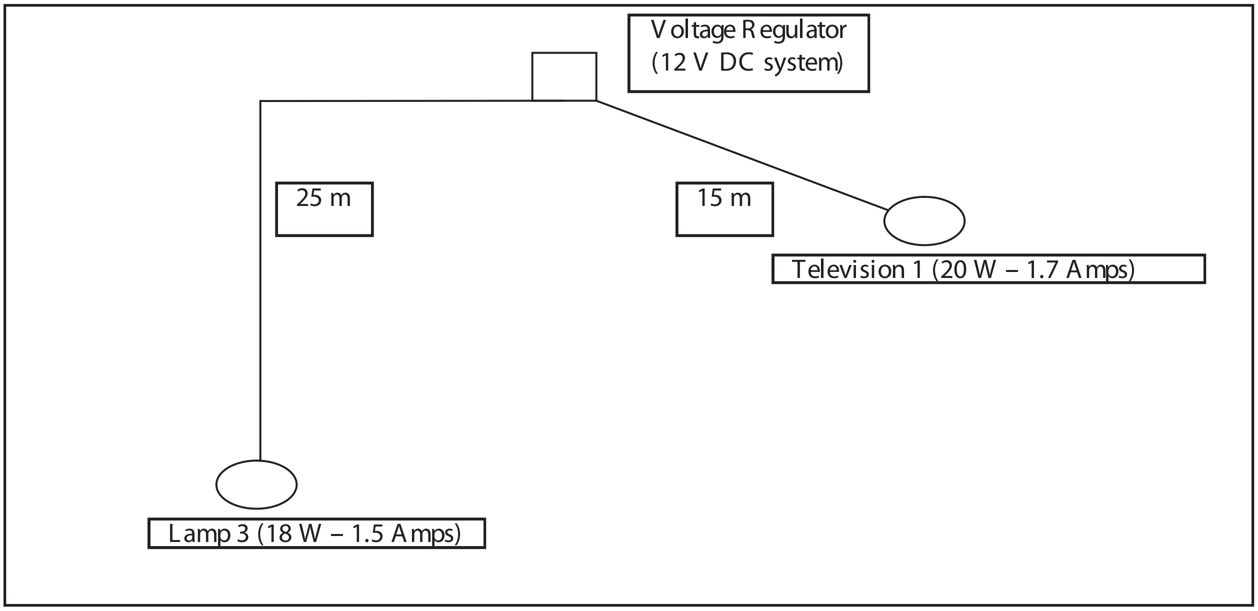
Select conductor caliber/size to result in a voltage drop of less than 3% for all wire connected to the voltage regulator. To calculate voltage drop, the system designer must employ a wiring diagram that clearly shows the location of loads, the maximum current of each load, and the distance from the loads to the voltage regulator. Using the known resistance of the conductor (derived using the American Wire Gauge scale – AWG, also known as the Brown & Sharpe wire gauge scale), the voltage drop can be calculated using Ohm's law.

For example, consider a solar home system that has two circuits, one for a single 18 watt lamp, and the second connecting to a 20 watt television. In the first circuit, the lamp is 25 meters from the voltage regulator, and in the second circuit, the television is 15 meters from the regulator. Using a wiring table, the designer can select the appropriate conductor for the solar home system, using a single conductor for both circuits by the following method. First, the designer must diagram the proposed wiring scheme, noting the location of the loads with respect to the source (or voltage regulator in this case), distance, watt power of each load, and maximum current. A simple wiring diagram for the above mentioned system can be seen in Figure 1.

After the designer has drawn the wiring diagram, he or she can proceed with calculating the voltage drop for each load. To do this, first the analyst must select a conductor gauge, which in essence is its diameter. The selection of which conductor gauge to employ is a function of the voltage drop across the whole system as well as cost. The larger the diameter of the wire, the lower the voltage drop will be, but the higher the cost. Therefore, the designer must be careful to balance technical design with cost.

Conductors selected should meet the worst-case scenario conditions of the system and its environment.

Figure 1. Sample wiring diagram



With these dueling criteria in mind, the analyst selects the conductor with the smallest diameter, which results in a voltage drop of less than 3%. For our case, let us assume selection of a 14 AWG gauge wire. Using the wiring table, we can deduce that this wire has a resistance of 0.008 ohms per meter. Then, multiply the wire lengths for both loads by this per meter resistance to obtain the resistance from the source to the load, R. After calculating the resistance in the wire, we can calculate the voltage drop for each load using Ohm's law, $I = V/R$ (equivalent to $V = IR$), or voltage equals current multiplied by resistance. Therefore, the voltage drop across that section of wire is the resistance multiplied by the current drawn by the load. This calculation yields the voltage drop within the circuit. Taking this voltage drop as a percentage of the circuit voltage results in the percentage voltage drop.

Table 4 presents a calculation for voltage drop using different conductor AWG gauges. The most applicable conductor gauge is highlighted because it allows for a voltage drop of less than 3% for all circuits while keeping conductor diameter to its lowest value. The 14 AWG gauge conductor is therefore most appropriate for this system.

For further information on voltage drop, refer to any credible electrical engineering text.

Table 4. Voltage drop calculation chart

AWG gauge	Conductor Diameter (mm)	R per km	R per m	R x 15 m	R x 25 m	VDtv	VDlamp	VDtv (%)	VDlamp (%)
1	7.348	0.406	0.000	0.006	0.010	0.010	0.015	0.09%	0.13%
2	6.543	0.513	0.001	0.008	0.013	0.013	0.019	0.11%	0.16%
3	5.827	0.646	0.001	0.010	0.016	0.016	0.024	0.14%	0.20%
4	5.189	0.815	0.001	0.012	0.020	0.021	0.031	0.17%	0.25%
5	4.620	1.028	0.001	0.015	0.026	0.026	0.039	0.22%	0.32%
6	4.115	1.296	0.001	0.019	0.032	0.033	0.049	0.28%	0.40%
7	3.665	1.634	0.002	0.025	0.041	0.042	0.061	0.35%	0.51%
8	3.264	2.060	0.002	0.031	0.052	0.053	0.077	0.44%	0.64%
9	2.906	2.598	0.003	0.039	0.065	0.066	0.097	0.55%	0.81%
10	2.588	3.276	0.003	0.049	0.082	0.084	0.123	0.70%	1.02%
11	2.304	4.133	0.004	0.062	0.103	0.105	0.155	0.88%	1.29%
12	2.052	5.209	0.005	0.078	0.130	0.133	0.195	1.11%	1.63%
13	1.829	6.570	0.007	0.099	0.164	0.168	0.246	1.40%	2.05%
14	1.628	8.282	0.008	0.124	0.207	0.211	0.311	1.76%	2.59%
15	1.450	10.444	0.010	0.157	0.261	0.266	0.392	2.22%	3.26%
16	1.290	13.172	0.013	0.198	0.329	0.336	0.494	2.80%	4.12%
17	1.151	16.610	0.017	0.249	0.415	0.424	0.623	3.53%	5.19%
18	1.024	20.943	0.021	0.314	0.524	0.534	0.785	4.45%	6.54%

CONCLUSION

The design, implementation and sustainability of rural electrification projects using stand-alone solar PV modules depends on both technical and social variables. A well-designed solar PV project must first take a macro look at the overarching factors influencing the project viability and sustainability. Project proponents must carefully look at variables affecting project identification (such as where donor investments are most likely to achieve pre-established development goals), the potential for a community organization to carry out the provision of service in the long-term, and the capacity and willingness of the community to pay for the cost of service delivered. Although these non-technical variables are often overlooked by the engineers designing solar PV systems, they form the backbone of a sustainable project.

Once these variables have been defined and analyzed, project proponents (whether they be a donor agency, non-governmental organization or community group) can set about defining the project. They then determine its scope, the energy service provider model to be used, and the energy supply and demand constraints of the community. When selecting a project's scope, the geographical distances and terrain of the project area are important factors. Implementing a project that incorporates a large number of houses with stand-alone solar PV systems may present costs that funders are not willing to bear when better alternatives exist. For example, mini-grid systems may be installed in areas where households are remote but clustered.

Regardless of the system design, some form of community organization must be established. This community organization fosters a sense of community ownership in the project, provides key feedback to the project designers on energy demand (mainly through a household survey), and allows for the selection and training of local technicians. In addition, if the community so decides, this entity may enable the establishment of a community energy service provider, which will locally manage and operate the solar PV systems. While there are a wide range of energy service provider models for these project, incorporating both community organizations and contracted private companies, NRECA recommends the training and establishment of a core of local technicians who can conduct both routine and troubleshooting maintenance. This reduces the cost of service for the local population and eliminates service delays when equipment or systems falter or fail.

A well-designed solar PV project must first take a macro look at the overarching factors influencing the project viability and sustainability.

The selection and design of a solar PV system's components is a relatively straightforward process, but it can be complicated for project proponents with limited technical ability. The principal components of a solar PV system include the solar PV panel, the battery, the charge controller, lamps, outlets, and connecting/mounting hardware. Solar PV systems are dimensioned based upon the daily energy consumption as determined through a household energy survey, the number of days of autonomy required, and the panel capacity, measured in peak watts (Wp). It is important to remember that product quality has a direct impact on project sustainability, but the same is true for maintaining costs within acceptable boundaries. The household energy survey, culminating in the willingness-to-pay and economic benefits analyses, can provide project designers with useful information on the final design parameters for the solar PV systems. Keep in mind that energy supply must match energy demand, along with ability and willingness to pay for the service.

When selecting system components, remember that all the different components interact. The PV module, battery, charge controller, wiring and lighting apparatuses do not operate in isolation. Each must be designed with the others in mind.

Stand-alone solar PV systems have been used in rural electrification programs to great success. A typical rural community's profile often displays a low level of economic development and/or opportunity, low population density, dispersed homes, and a low level of energy consumption. Often, due to the remote location of these communities, they represent low-level priorities within a national or private electricity company's electrification plans, and they may never have access to modern energy services. Under these circumstances, stand-alone solar PV projects provide an efficient, cost-effective, and beneficial development for the community. This is not to say that they are without risk or potential for failure. However, the implementation and operation of solar PV systems through an associated community energy service provider within a rural community can create a level of energy service that provides multiple economic and social benefits. ■