Guides for **Electric Cooperative Development and Rural Electrification**

USAID
FROM THE AMERICAN PEOPLE

NRECA International Ltd.
Your Touchstone Energy® Partner

Glossary of Abbreviations

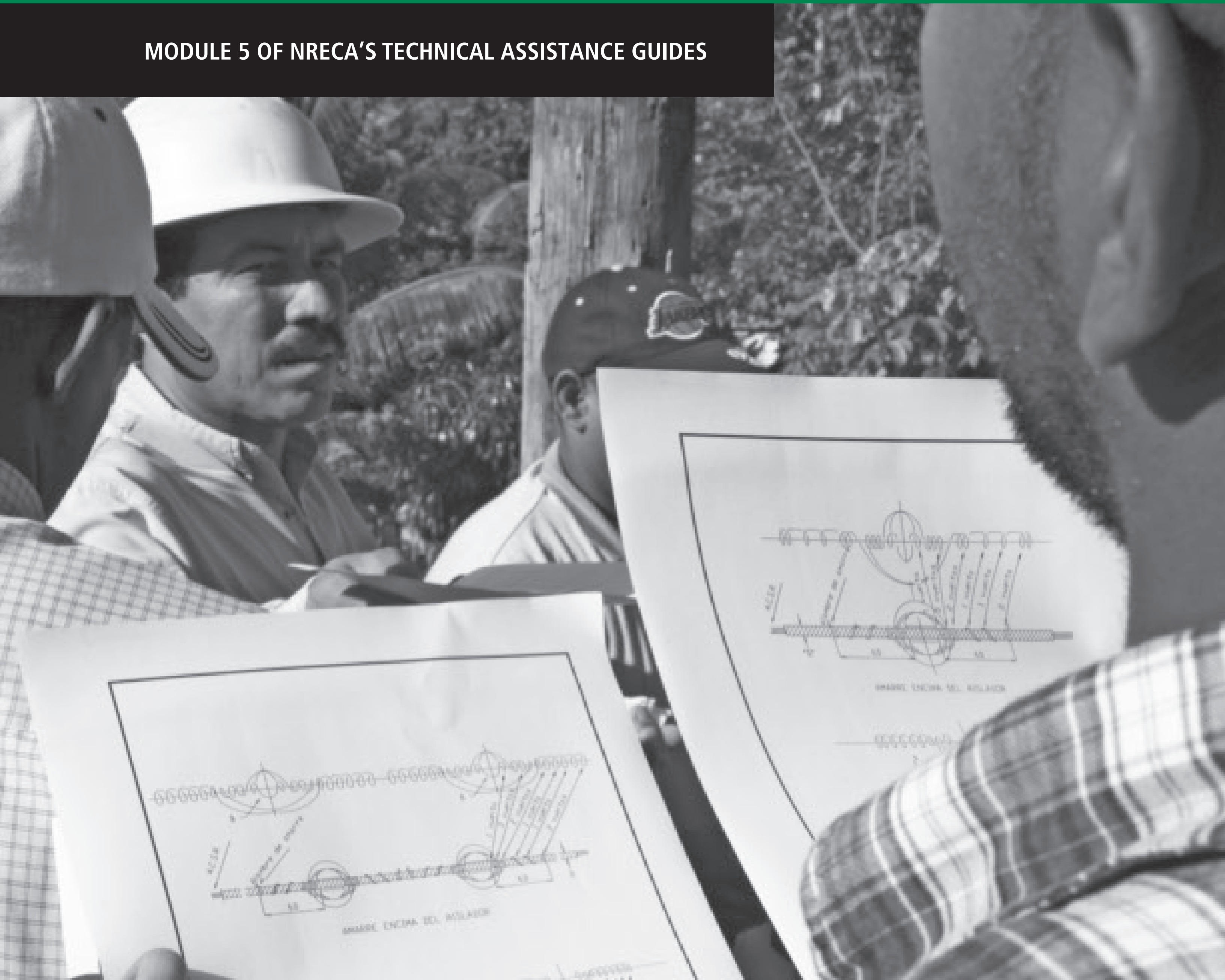
A	Ampere
AH	Amp-hour
AC	Alternating current
ACSR	Aluminum conductor, steel reinforced
A&G	Administrative and general
AWG	American wire gauge
CARES	Central American Rural Electrification Support Program
CCT	Correlated color temperature
CDA	Cooperative Development Authority (Philippines)
CEF	Fronteriza 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

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.

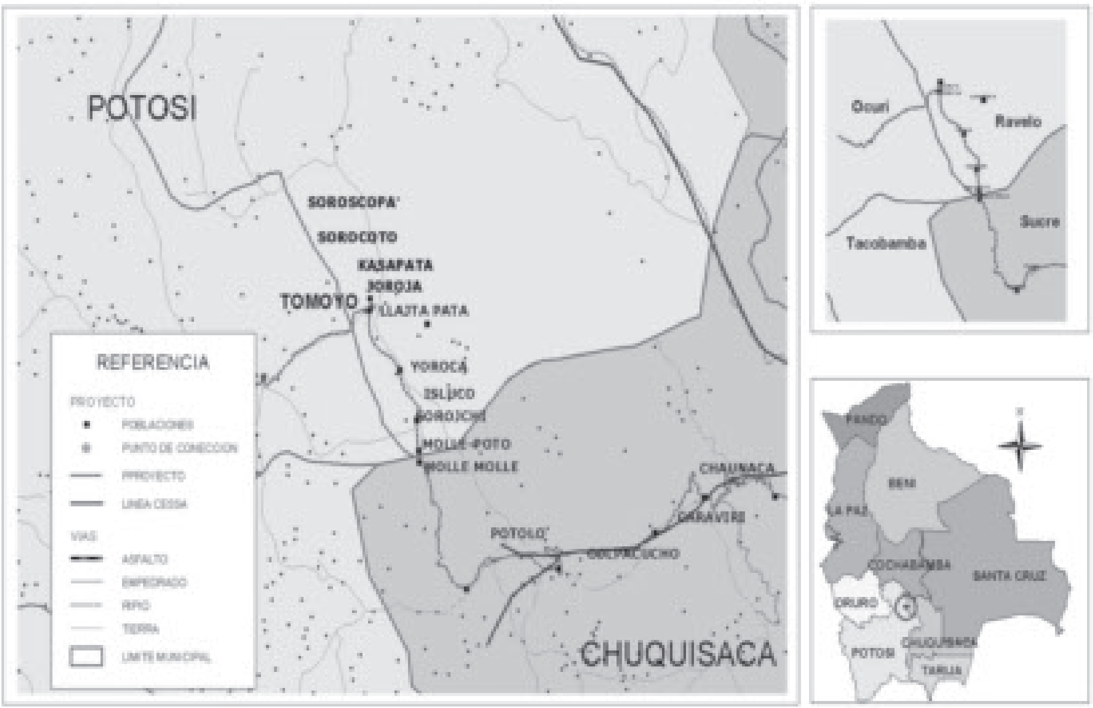
After defining the project area, the gathering of demographic and infrastructure data starts, along with the organization of the analysis process. Most project data, especially data containing spatial attributes, are organized using geographic maps. With the recent advent of GIS, it has become more common 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



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

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

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

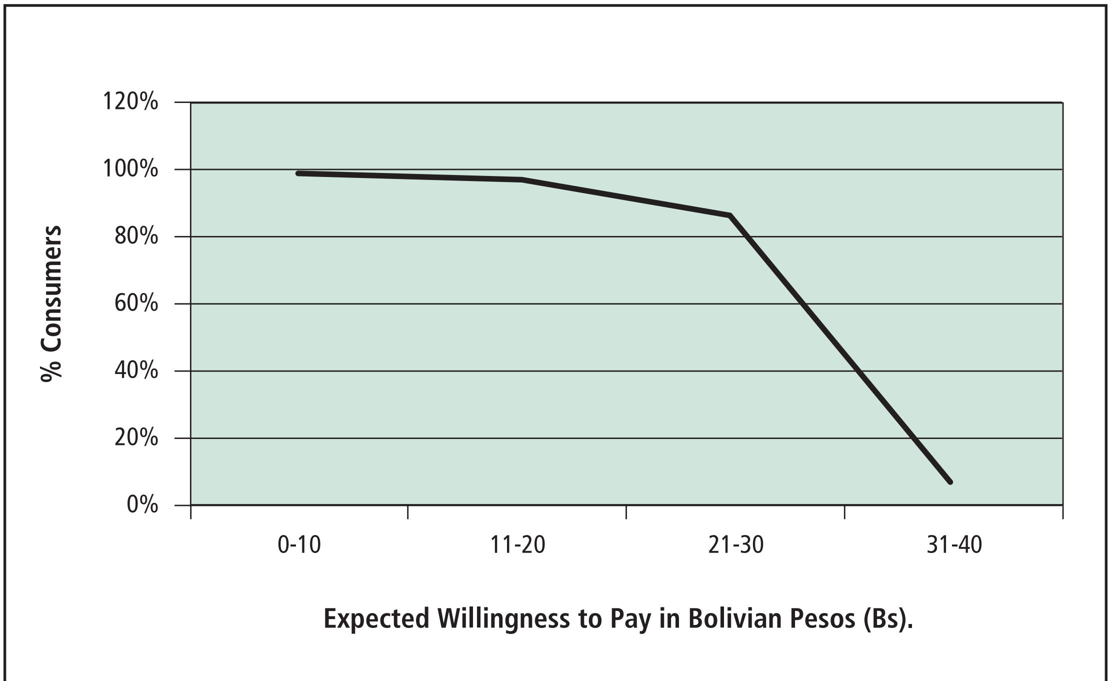
As shown in Figure 3, the Tomoyo project's willingness-to-pay study indicates that up to 85% of the population is willing to pay up to 25 Bs/month for electricity. However, to project future electricity consumption and demand, the analyst must classify the users into their respective consumer categories 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**

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

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

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

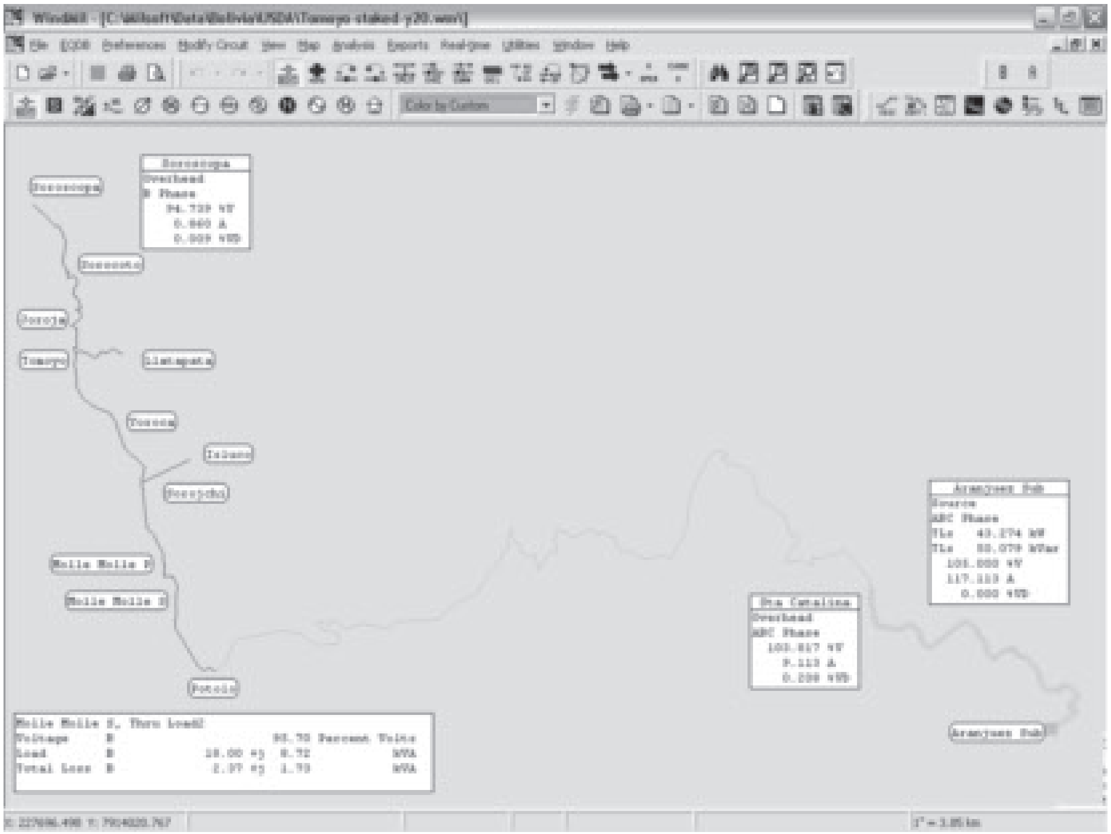
A central concern of all government agencies and international donors is how to minimize project cost, while meeting service quality and safety standards. If a project disregards service quality and safety standards, this causes an increase in future operating costs for the electric distribution service 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.

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

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.

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.