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

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Glossary of Abbreviations

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

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

*English translation of Spanish abbreviation

Calculating Consumer Willingness to Pay for Electric Service and Economic Benefits of Electrification Projects

MODULE 6 OF NRECA'S TECHNICAL ASSISTANCE GUIDES

6

EXECUTIVE SUMMARY

Successful rural electric cooperatives and successful rural electrification programs have utilized different systems and methodologies to identify and prioritize project investments. Because electrification is highly capital intensive and financial resoures are finite, it is critically important to determine empirically which projects are technically and financially feasible. This requires applying a consistent methodology to analyze the proposed projects and prioritize investments accordingly. NRECA has developed an objective methodology to analyze and then prioritize electrification projects. This module illustrates the various steps and tasks involved in the application of this methodology.

From a broad perspective, this module contributes to a more objective classification of electrification projects so as to optimize the investment of development funds. More specifically, it provides a comprehensive guide on how to estimate consumer willingness to pay (WtP) for electric service and the economic benefits of electrification projects. The WtP study and the analysis of economic benefits are extremely important to determine the technical, financial, and economic feasibility of electrification projects, particularly in rural areas. The WtP studies use comprehensive surveys of households with and without current electric service to determine, in the most reliable way possible, their actual consumption of and expenditures on energy over a defined time period. The data collected from these household energy use surveys illustrate the consumers' "revealed" WtP for electric service. Likewise, the economic benefit to the consumer is calculated using the data compiled from surveys and other reliable sources. The economic benefit represents the incremental value of utilizing higher energy value and lower cost per unit of electric service in place of alternative energy sources such as: candles, kerosene lamps, and batteries for lighting and household appliances. Completing the economic benefit analysis can allow the electric cooperative, government and/or other interested party to prioritize investments. The analysis is also useful in determining whether a capital subsidy is required for the project to be feasible, and if so, its level and duration. Its principles complement and supplement the other tasks involved in rural electrification project analysis, including demand assessments, engineering design, and financial analysis. The combined results of these different analyses determine the ultimate feasibility of the project.

This module includes brief explanations and guidance to help the practitioner conduct an energy use survey, calculate consumer WtP for electric service, estimate the economic benefits of an electrification project, and present the results.

Provided for the reader are three examples to illustrate the details involved in the application of the methodology. Whenever applicable in a specific step, the module mentions tools that may facilitate the process. For example, NRECA has developed many survey instruments and an electronic calculation model/worksheet to determine the economic benefits of electrification projects. The module also mentions software programs that are very useful in data entry, management, and reporting.

The two fundamental concepts for this module are consumer willingness to pay and economic benefit. These concepts are defined as follows:

Because electrification is highly capital intensive and financial resoures are finite, it is critically important to determine empirically which projects are technically and financially feasible.

- *Willingness to pay:* The maximum amount that an individual indicates that he or she is willing to pay for a good or service.

- *Economic benefit:* The increased benefit that a recipient could receive from a proposed project compared to his or her present situation. In the case of an electrification project, it indicates the attributed benefit of the electric service in monetary units, versus the use of current energy alternatives.

When analyzing an electrification project, we must know if the consumer willingness to pay for electric service will be sufficient for the project to be financially feasible. A critical mass of potential consumers must be able to demonstrate that they have the means and willingness to pay a monthly electricity bill, which is calculated by multiplying actual electricity consumption in kilowatt-hours (kWh) by the electricity tariff rate. In addition, to justify the implementation of the project, the economic benefit to consumers over the life of the project must surpass the capital cost expended to develop it.

INTRODUCTION

Successful rural electric cooperatives and successful rural electrification programs[1] have employed a variety of different systems and methodologies to identify and prioritize project investments. Because electrification is highly capital intensive and financial resoures are generally finite, it is critically important to determine empirically which projects are technically and financially feasible. This requires applying a consistent methodology to analyze the proposed projects and prioritize investments accordingly. NRECA has developed an objective methodology to analyze and then prioritize electrification projects. This module illustrates the various steps and tasks involved in the application of this methodology.

[1]Barnes, Douglas, *The Challenge of Rural Electrification: Strategies for Developing Countries* (Washington, D.C.: Resources for the Future, 2007).

Reliable data on energy expenditures among potential consumers in a target project area are vital to ensure the accuracy of the willingness-to-pay (WtP) assessment and economic benefit analysis. This module explains how to obtain these data, calculate consumer WtP, and estimate the economic benefits of an electrification project. The financial feasibility of an electrification project depends in large part on the capability of a critical mass of users to pay a residential tariff that generates sufficient revenue for the electric cooperative to cover the costs of operating and maintaining the distribution system. A project whose financial feasibility is based on erroneous assumptions about consumer willingness to pay will not be sustainable. Planners can prevent this error by conducting an adequate consumer willingness-to-pay study in the target project area.

This module provides the experienced WtP practictioner with a practical manual for basic reference on WtP and economic benefit analysis. It also enables the neophyte to carry out a consumer WtP study and estimate the economic benefits of electrification projects using data compiled from field surveys and other resources. This module is not intended to serve as a reference on financial or statistical analysis of projects.

Essential Definitions

Readers will more easily understand and apply the guidelines in this module with the following definitions of key concepts in mind.

- *Economic analysis:* analysis that shows the economic feasibility of a project, from the perspective of the user as well as that of the host country.

- *Financial analysis:* analysis of financial feasibility, which illustrates whether the project will be profitable or not, from the perspective of the electric cooperative or utility that will execute and operate system.

- *Economic benefit:* the increased benefit that a beneficiary could receive from a proposed project compared to his or her present situation. In the case of an electrification project, this represents consumers' monetary benefit accruing to from the use of electricity when compared with their use of current energy alternatives.

- *Alternative sources of energy:* candles, kerosene, dry cell and car batteries, and other fuels and materials used as sources of energy for lighting and appliances in the absence of reliable electric service. Note: This module does not quantify certain common energy resources, such as biomass for cooking, for which electricity is not a direct substitute.

- *Demographic study:* the study of the project's target population to identify and determine distinct characteristics that would affect project feasibility.

- *Demand study:* in the context of an electrification project, this study determines the demand for the electric service that will exist in terms of number of users, amount of energy consumption, and power required. The aforementioned study includes an estimate of the initial demand, as well as projections for future demand.

- *Willingness to pay:* the maximum amount that a person indicates that he or she is willing to pay for a good or service.

- *Expressed willingness to pay:* the maximum amount that a person expresses that he or she is willing to pay for electric service, typically registered in monetary units/month, in response to a specific question.

- *Revealed willingness to pay:* the maximum amount that a person indicates that he or she is willing to pay for a product or service through their actual expenditures on alternatives or substitutes for the actual good or service in question. For an electrification project, this refers to a situation where electric service has limited hours or is subject to frequent and prolonged blackouts, requiring consumers to resort to alternative energy sources for lighting and other household energy applications. In such instances, the cost of alternative resources of energy and the cost of electricity (if the individual already receives some type of electric service) are included in the WtP calculation.

Purpose

This module contributes to a more objective classification of electrification projects, so as to optimize the investment of development funds. More specifically, it provides a comprehensive guide on how to estimate consumer willingness to pay for electric service and the economic benefits of electrification projects. Its principles complement and supplement the other tasks involved in rural electrification project analysis, including demand assessments, engineering design, and financial analysis. The combined results of these different analyses determine the feasibility of the project.

The content of this module will help the practitioner conduct an energy use survey, calculate consumer willingness to pay for electric service, estimate the economic benefits of an electrification project, and present the results. Incldued are brief explanations and guidance on the following 17 steps:

1. Identify the information needed.

2. Define the variables.

3. Formulate the necessary questions for the survey.

4. Design and test the instrument.

5. Design the database.

6. Define the target population.

7. Determine the size of the survey sample.

8. Establish a sample framework. and produce a map of the project area.

9. Select a random sample.

10. Instruct the enumerators.

11. Conduct and supervise the survey.

12. Enter, revise, and tabulate the data.

13. Analyze the data.

14. Calculate consumer willingness –to pay.

15. Calculate the economic benefits.

16. Present the final results.

17. Use the results in the technical and financial analysis.

It is important to demonstrate that the project's economic benefit is higher than the actual capital costs required to develop the project's infrastructure.

After reviewing the steps summarized above, the reader can better grasp the importance of synergy among the various tasks, such as harmonizing the database design with the survey instrument.

Whenever applicable within a specific step, the module mentions a few tools to facilitate the practitioner's task at hand. For example, NRECA has developed many survey instruments, including various financial models to determine a project's economic benefit to consumers. The module also mentions software programs like Epi Info, Microsoft Access and Excel, which are useful for organizing and analyzing data.

Global Perspective of this Module

This module was designed for use in developing countries. The concepts, terms, and methodology of this module are broadly applicable. Our wish is that it may be useful for experienced economists, as well as for those new to the use of willingness to pay and economic benefit analysis for electrification projects.

Although this module has broad application and NRECA has used this methodology in several countries, project analysts should always be careful to make the necessary adjustments for local conditions. Socioeconomic realities vary from one country to the next and from one project to the next. Practictioners must supervise and adjust the methodology's application to ensure results of the highest quality.

THEORY AND CONCEPTS OF WILLINGNESS TO PAY AND ECONOMIC BENEFITS

To justify the financing and development of an electrification project, the target population must demonstrate sufficient ability and willingness to pay for the electric service offered. It is important to demonstrate that the project's economic benefit is higher than the actual capital costs required to develop the project's infrastructure. The key concepts in such a determination are defined as follows:

- *Willingness to pay:* The maximum amount that an individual indicates that he or she is willing to pay for a good or service.

- *Economic benefit:* The increased benefit that a recipient could receive from a proposed project compared to his or her present situation. In the case of an electrification project, it indicates the attributed benefit of the electric service in monetary units, versus the use of current energy alternatives.

Willingness to Pay

Economists define "effective demand" as the demand for goods and services that are backed by the resources to pay for it. Consumer "effective demand" or willingness to pay (WtP) is determined through data acquisition and analysis from consumers in the proposed project area. Using interviews conducted in the field, analysts determine, in the most reliable way possible, the actual expenditures for existing energy sources, and other aspects of their economy that indicate the availability of resources to pay for the electric service. For an electrification project, data are collected from surveys and other reliable sources of information to determine, through empirical and quantifiable analysis, what a target population is willing to pay for the electric service.

For example, researchers ask the interviewees what they currently pay for alternative sources of energy like kerosene, candles, batteries, or for electricity in the case of communities already receiving some sort of electric service. This is known as "Revealed WtP" because it reveals what the consumer is actually paying for a good or service.

Researchers can also describe to the consumer a hypothetical electric service and then ask for the maximum amount they consumer would be willing to pay for such service. This methodology is known as "contingent valuation" because it implies the creation of a realistic scenario in which the interviewer offers the consumer a reliable electric service at a rational rate which is also feasible for the project. The method yields what is known as "Expressed WtP" because it reflects what the consumer expresses that he or she is willing to pay. This methodology can be very subjective and unreliable because the potential beneficiaries may not know enough about the service and its benefits to be able to offer a realistic response, or they may offer a high but unrealistic figure in the hopes that it might increase the potential for electric service.

NRECA uses both methodologies to determine the consumer's WtP. However, the Revealed WtP results provide preferable input for the project financial analysis because they reflect the consumer's actual expenditures on existing energy sources. The Expressed WtP is subjective, reflecting a consumer's perception of the value of the electric service. Nevertheless, it is useful as a basis for comparison with consumers' actual expenditures on energy sources, reflected in the Revealed WtP.

Economic Benefits

Multiple benefits result from the electrification of a community. NRECA's analysis of lighting cost and output across a variety of countries has unequivocally demonstrated that the provision of light via an electrical source provides exponentially greater lighting value at a fraction of the cost of traditional fuels and lighting appliances, such as kerosene lamps or candles. In addition to the visible and instantly recognizable benefits associated with cheaper and more efficient lighting, other benefits relate to education, health, entertainment and communication, comfort and protection, convenience, the environment, and productivity.

While empirical analysis has identified and quantified some of these benefits,[2] many of the benefits resulting from electrification are difficult and costly to quantify. Thus, not all of the benefits figure into the analysis described in this module. Although the methodology presented here is practical and sufficient to analyze and classify electrification projects, by no means does it capture all of the ancillary benefits of an electrification project. The NRECA economic benefit methodology is conservative in nature, and we acknowledge that the total project economic benefit may be much greater than the more narrow benefits quantified through this process.

This module describes how to estimate the economic benefit derived through changing from using alternative sources of energy to the use of grid-based electricity. Regardless of the source of generation, distributed electricity delivers a much greater energy value per unit at a lower price than any traditional energy source. (The units are the lumen for light or kWh for appliances.) This methodology quantifies the economic benefits the

[2]See *"Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits",* ESMAP Report 255/02, May 2002.

consumer receives when electricity substitutes for traditional energy sources like candles, kerosene, gas, and batteries.

First, analysts gather information on consumption and expenditures on alternative sources of energy among non-electrified consumers in the target project area. From that information, analysts calculate the individual consumer's economic benefit, which in turn helps them determine the overall economic benefit of the project. In some cases, economic benefit analysis also incorporates data and information on consumer expenditures and consumption of energy in communities that already receive electric service.

Important considerations within the calculation of consumer economic benefit are the costs associated with traditional fuels, in addition to the capital and maintenances costs for the appliances and equipment.

The total economic benefit for the consumer in communities without electricity is the sum of two related but independent calculations. The first only includes expenditures and consumption for household lighting. The second includes expenditures on, and consumption of, alternative sources of energy used for household appliances such as gas or kerosene refrigerators, battery-operated radios, or the associated costs necessary to acquire and operate a generator, among other appliances and power generation sources.

In isolated low-income rural communities, such as those found in the Department of Potosí in Bolivia, the project consumer's economic benefit is mostly associated with lighting. Electrical appliances are rare in such communities. Consumers might be spending money on biomass or propane gas for cooking, but for cultural and financial reasons electricity is generally not a direct substitute for these energy sources. Thus such expenditures are not considered when estimating consumer willingness to pay for electricity and determining the economic benefits of an electrification project. On the other hand, in some communities with more economic resources, such as in some parts of the Dominican Republic, many appliances and generators are in use, so that the economic benefit from other uses of energy could be higher than that for lighting.

Important considerations within the calculation of consumer economic benefit are the costs associated with traditional fuels, in addition to the capital and maintenances costs for the appliances and equipment. Normally NRECA does not obtain information on capital costs for small devices such as candleholders, lanterns, and lamps, which are assumed to cost less than US$20. For example, when using candles, the interviewer asks how many candles are used per month and the cost of the candles. The researcher does not ask the cost of the candleholders, assuming that these are sometimes not used or that they have little influence over the final cost of the candles. However, when dealing with an electricity generation system, or a backup system such as an inverter, small generation unit, or photovoltaic system that includes panels and batteries, the capital and maintenance costs can be significant and should be accounted for in any economic benefit calculation. The capital cost for small household photovoltaic systems ("SHS") could vary from US$250 to 2,500, depending on the size of the system in watts peak (Wp). In these cases, analysts normally use a "straight line" depreciation table that considers the lifetime of the equipment.

Economic Benefit for Lighting

The first step in the process of determining the lighting economic benefits of an electrification project is reviewing price data and consumption levels for traditional fuels used for lighting purposes. As previously explained, this is done through the willingness-to-pay survey. However, given that fuels are dissimilar, and that the amount of light generated from dissimilar lamps varies widely, it is necessary to convert lighting data to common units. Light intensity is measured in lumens, with light output expressed as kilolumenhours per month (klmh/month). The kilolumenhour (klmh) is a measurement of the value of light obtained from an energy source in an established period. The unit is a lumen. As an example, according to a study performed by the World Bank, a candle emits from 11-16 lumens, while a gas lamp has a range of 300-700 lumens.[3] The cost associated with lighting is expressed in cost per kilolumen-hours ($/klmh). After completing the cost analysis, the analyst can organize the cost data for easy comparison between the cost of electrical lighting and the cost of light generated by alternative lighting/ energy sources. Thus, it becomes possible to evaluate the financial or economic benefits for the two distinct alternatives in graphical form. The variables evaluated in this process include:

- The price of light produced (US$/klmh)
- The quantity of light produced for this priceper month (klmh/month)
- The price of light produced by using an electric lamp (US$/klmh)
- The electricity consumption associated with use of electricity for lighting purposes

Next, to the analyst graphs these values. Figure 1 illustrates a simple comparison of an electric lamp to a lamp using a traditional fuel, such as kerosene. It demonstrates the economic benefit accrued to the consumer who makes the transition from a traditional fuel and lighting source to electricity. The consumer pays a lower price, and receives more light at the lower price. The accrued economic benefit is called a consumer surplus. In Figure 1, it equals the area above the corresponding horizontal price line and below the demand curve. The consumer surplus represents the economic value received by the consumer through electrification at no additional cost.

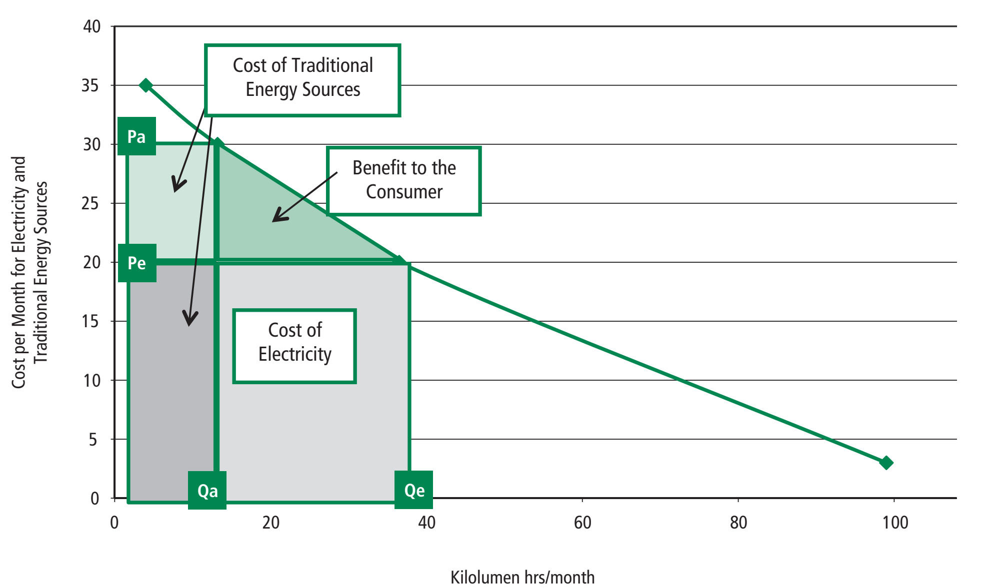
The monthly cost for alternative energy sources is represented by the rectangle (Pa * Qa). For an electrification project, the cost of electricity per month appears in the rectangle (Pe * Qe).

The data presented in the graph illustrate that electricity offers the consumer a more efficient lighting source, with a greater return, and at a much lower price, when compared to alternative energy sources. The surplus or benefit to the consumer is represented by the sum of the triangle

((Qe-Qa)*1/2(Pa-Pe)) and the rectangle (Qa*(Pa-Pe)).

[3] See Table A3.1 in Robert van der Plas and A.B. de Graaff, *A Comparison of Lamps for Domestic Lighting in Developing Countries,* (Washington, D.C., World Bank Industry and Energy Dept.: 1988).

Figure 1. Lighting demand curve.



Equation 1. Formula to calculate the economic benefit for lighting[4]

D = Qa*(Pa-Pe)+((Pa-Pe)/2)*(Qe-Qa)		
Where:		
Pe	Price of Electricity	US$/klmh
Pa	Price of Traditional Energy Sources	US$/klmh
Qe	Consumption of Electricity for Lighting	klmh/month
Qa	Consumption of Traditional Energy Sources for Lighting	klmh/month

The preferred methodology for determining the economic benefit associated with the utilization of electricity for non-lighting household applications is very similar to the methodology to calculate the economic benefit for lighting.

Equation 1 presents the formula used to determine the consumer economic benefit resulting from a switch to electricity from traditional lighting sources.

Equations 1, 2 and 3 present the specific formulas for calculating the consumer economic benefit that results from the switch to electricity for lighting and non-lighting applications, such as powering radios or televisions.

Economic Benefit from Other Energy Use

Two methodologies determine the economic benefit for energy use not associated with lighting. The first is based on actual expenditures on, and consumption of, traditional energy sources that are not associated with illumination. The second is based on electricity consumption for non-lighting purposes and the associated electricity tariff. The first methodology is more exact, precise, and analytically rigorous. However, it requires more data, effort, and time to calculate than the latter.

The project manager and lead analyst must decide between the two methodologies. To decide, assess the financial conditions of the communities, the data collected from expenditures and consumption of energy sources for non-lighting applications, and the level of detail required to justify the investment or to determine the level of subsidy. For example, the current energy use patterns in the Dominican Republic and Bolivia discussed above would point toward differing methodologies used for this phase of the economic analysis.

Methodology Utilizing Data on Actual Energy Use and Consumption

The preferred methodology for determining the economic benefit associated with the utilization of electricity for non-lighting household applications is very similar to the methodology to calculate the economic benefit for lighting. However, its unit of measurement is the kilowatt-hour (kWh), rather than the kilolumen-hour (used to measure lighting). The formula and methodology to calculate the economic benefit for lighting and non-lighting applications are the same – the only difference is in the units of measurement. For the formula to calculate the economic benefit for non-lighting applications, see Equation 2.

This methodology is relatively precise because it takes into account the actual operating cost and the energy consumption (in kWh) associated with household electrical appliances.

The use of this methodology depends on specific data obtained from household surveys on the

Equation 2. Formula to calculate the economic benefit for other uses of energy

D=Qa*(Pa-Pe)+((Pa-Pe)/2*(Qe-Qa)		
Where:		
Pe	Price of Electricity	US$/kWh
Pa	Price of Traditional Energy Sources for Other Uses	US$/kWh
Qe	Consumption of Electricity for Other Uses	kWh/month
Qa	Consumption of Traditional Source of Energy for Other Uses	kWh/month

Source: World Bank

[4]World Bank Report 255/02 "Rural Electrification & Development in the Philippines: Measuring the Social & Economic Benefits", May 2002.

energy consumption used for all household electrical appliances. However, this is neither simple nor straightforward, as each household often uses various types and brands of electrical appliances that consume energy from different sources. This can result in an enormous amount of information that requires great effort to compile, digitize, organize, and analyze. One way to reduce some of the required effort is to record all the household electrical appliances and hours of use per day, and estimate average power and/or consumption by appliance, rather than determining the actual energy specifications of each appliance and requesting specific information on its use within the household. The most precise way would be to write down the power of all the appliances, but such data are not always available. Instead, analysts can use an average of power for each device based on homologated charts.

This methodology is easier to apply in areas where consumers use only a few household electrical appliances. In Bolivia, NRECA's team used this methodology for the economic benefit analysis of communities in Potosí (the Tomoyo project) because the only electric device in frequent use was the radio, whose energy came from dry cell batteries. Not much time was required to calculate the average consumption and expenditures from one device and for only one energy source. Using the formula indicated in Equation 2, we were able to calculate the economic benefit of US$11.50/month for other energy uses for the Tomoyo project.

Methodology Using Data on Energy Use and Consumption in Similar Areas

An alternative methodology for calculating the economic benefit of energy use for electrical appliances utilizes recorded data on electricity consumption for non-lighting purposes in similar communities that are already electrified. Instead of recording actual consumption and cost of energy sources for non-lighting appliances, analysts simply multiply the kWh consumed for all non-lighting energy uses (including radios, televisions, irons, fans, etc.) in similar communities that are already electrified by the actual cost of power in US dollars per kWh. This formula appears in Equation 3.

This way of calculating the benefit of additional kWh consumption for other uses in non-electrified areas hinges on the assumption that if every individual is willing to pay for the electric service, then it is justified to assign a value at least equivalent to that of the prevailing retail residential electric rate. While this methodology does not necessarily capture the total economic benefit for non-lighting energy uses, it is still used as an easy and conservative way to determine at least part of the benefit.

For instance, if the total consumption of an average rural household is 50kWh/month and 20 kWh are used for lighting, the economic benefit of the additional 30 kWh used for appliances is estimated by multiplying 30 kWh times the residential retail electric rate. If the rate is US$ 0.10/kWh, then the benefit of the additional kWh is US$ 3/month.

In non-electrified areas where residents frequently use a variety of household electrical appliances and energy sources, the project managers must make an informed decision concerning the use of the two methodologies described above. They must carefully take into account the circumstances of the region, the time and resources available, and the precision of the data needed to make further decisions.

An alternative methodology for calculating the economic benefit of energy use for electrical appliances utilizes recorded data on electricity consumption for non-lighting purposes in similar communities that are already electrified.

Equation 3. Alternative formula to calculate the economic benefit of other energy uses

$D = Pe^{*} Qe$
Where:
Pe = Price of Electricity (US$/kWh)
Qe = Consumption of Electricity for Other Uses (kWh/month)

Calculation of Total Economic Benefit

Calculation of total economic benefits simply requires the analyst to add up all the economic benefits generated by converting from traditional fuel sources to electricity. One way of presenting the economic benefits of electrification to a consumer is through monetary units per month. However, to estimate the maximum benefits that the project will generate, and hence, the maximum subsidy that should be considered for the project through capital subsidies, analysts should evaluate the net present value (NPV) of the economic benefits. Project teams may calculate the net present value by adding all the lighting and non-lighting benefits over the life of the project, and evaluating these benefits together as a single item. The net benefits are normally expressed as the net present value of the benefit stream.

NRECA makes the necessary adjustments to this basic methodology according to the existing conditions of the country, region, and the communities where the study will be conducted.

METHODOLOGY FOR ESTIMATING WILLINGNESS-TO-PAY AND ECONOMIC BENEFIT

We now turn to the methodology to conduct consumer willingness-to-pay studies and economic benefit analysis. While the methodology for both activities should be consistent and rigorous, conditions within the project's community dictate the details of its application. Flexibility may be needed to account for issues involving data, consumer characteristics, geography, topography, etc. NRECA makes the necessary adjustments to this basic methodology according to the existing conditions of the country, region, and the communities where the study will be conducted.

At the conclusion of a WtP and economic benefit study, the project team knows how much the target population would be willing to pay for electric service and what the estimated economic benefit of the project would be if it were developed. These dual goals drive all steps of the methodology.

Of course, the final results of the process depend entirely on the quality of the data collected and the precision with which is the data are analyzed. Errors can be made in determing appropriate sample size, recording data during consumer enumerators, or while transferring data from survey forms to an electronic database, etc. Errors made at any point in the process negatively affect the integrity of the results and could negatively affect decisions regarding project development.

Minimize errors by carefully determining the sample size and its randomization in the following ways:

- Closely following the field procedures for conducting consumer interviews
- Supervising the field work to ensure the gathering of the highest quality of data
- Conducting a careful data entry process
- Performing a detailed review of the database prior to analysis
- Verifying in detail the formulas and procedures for the data processing and analysis
- Reviewing the final presentation of results to ensure that it is error-free

The application of the methodology is illustrated through two projects: the Tomoyo project in Bolivia (a project with 600 consumers) and the Cooperativa Eléctrica Fronteriza (Fronteriza Electric Cooperative – CEF) project in the Dominican Republic (a project consisting of 17,000 consumers). Practical examples from other projects illustrate certain key issues, practices and/or results.

As part of a rural electrification program financed by the USDA, NRECA conducted a study of consumer willingness to pay and an economic benefit analysis of a potential rural electrification project planned for several communities in rural

Bolivia. The proposed project was located in Tomoyo, which borders the departments of Chuquisaca and Potosí, respectively, and which is north of the city of Sucre. The Tomoyo project would extend the existing electricity grid from the town of Potolo up to Llajtapata, resulting in electricity access for six communities with approximately 600 potential consumers. NRECA conducted interviews in each of the six communities located along the main project route, including Molle Molle 1, Molle Molle 2, Sorojchi, Yoroca, Tomoyo, and Llajtapata. Maps highlighting the Tomoyo project are presented in Module 5.

Researchers also conducted various field survey interviews with consumers in the town of Potolo, which already had electric service. Analysts used this information as a basis for comparing information on energy consumption and expenditures in the six communities that encompassed the project.

In a southwestern area of the Dominican Republic, NRECA conducted a consumer willingess to pay study and an economic benefit analysis of a proposed rural electric cooperative and electrification project. The proposed project included the communities of Las Matas de Farfán, Comendador, El Cercado, Hondovalle, Matayaya, El Llano, Bánica, and Pedro Santana—collectively referred to as the Cooperative Electrica Fronteriza (Fronteriza Electric Cooperative or CEF).

Identifying the Necessary Information and Questions

Since consumer WtP greatly affects the determination of project feasibility, it is important to verify its results using several tools. For the Revealed WtP, this includes gathering data concerning all current expenditures for energy sources that would no longer be purchased once the population has reliable electric service. For example, the survey would ask how much the household spends on candles, dry cell batteries, kerosene, and other liquid fuels for lighting. It would pose similar questions for consumption of and expenditures on traditional energy sources for appliances, including dry cell batteries or car batteries to power radios and small televisions, kerosene or propane gas for refrigeration, as well as diesel for water pumps, small portable power generators, and other internal combustion engines and equipment used for household or business purposes. The data on current expenditures for traditional energy sources used for lighting and appliances serve as an acceptable estimate of what that household could pay for electric service.

In addition to questions on consumer expenditures on traditional energy sources, it is useful to ask questions that might provide supporting evidence regarding whether the target population has enough income to pay for electric services. This could include questions regarding expenditures on other goods, such as housing, food, transportation, education, health, and telecommunications, such as cell phones. Data on expenditures for these types of goods and services could also provide useful indicators of how much the consumer or household would be willing to pay for electric service.

After completing a list of data requirements needed to determine consumer WtP, one can then focus on the data requirements of an economic benefit analysis. Based on Equation 1, the data required to calculate the consumer and project economic benefit would include the electricity tariff, along with the cost and consumption of traditional energy sources. Two methods provide for estimation of the electricity tariff. First is the use of a proxy tariff in an adjoining electrified village. Second is estimating consumer penetration based on consumer WtP and calculating a cost of service tariff that would provide sufficient revenue to cover the utility's operating and maintenance costs.

As previously explained, the four main variables used to calculate the project economic benefit (for lighting) are:

Pe = Price for electricity (US$/klmh)

Qe = Quantity of electricity (klmh/month)

Pa = Price of alternative energy sources (US$/klmh)

Qa = Quantity of alternative energy sources (klmh/month)

Estimates for consumption of electricity (Qe) can be determined by means of household surveys that collect data on electricity consumption in villages that are currently electrified and have similar socio-economic conditions to those prevalent in the proposed project area. A second method of estimating electricity consumption is through data provided by electric utilities that previously served consumers in the area. Survey questions ask about the use and type of light bulbs (incandescent or fluorescent, for example), as well as electric appliances. In addition, the researcher would ask to see electric bills from previous months to record the actual consumption of kWh/month. Whenever possible, obtain data on average electricity consumption for each user category (residential, commercial, industrial) from the electric utility that serves the project area. To standardize the data to determine the economic benefit, one must convert klmh/month to kWh/month using the conversion factor for both incandescent and compact fluorescent bulbs.

The data on current expenditures for traditional energy sources used for lighting and appliances serve as an acceptable estimate of what that household could pay for electric service.

To obtain values for the Pa and Qa variables, the practictioner needs to ask questions concerning the amount and cost of alternative energy sources. The examples below explain this process for a solid fuel (candle) and a liquid fuel (kerosene) potentially used for lighting purposes. Follow the same procedure to ask questions concerning any other alternative energy sources.

The data required to determine expenditures on, consumption of, and the energy value obtained from the usage of candles by a household require several interrelated questions. First formulate a question about the number of candles consumed in a finite time period, such as a week or a month, and then inquire about the cost of candles. We also want to know how many kilograms of candles are used per month so that we can convert that amount of weight into lighting value in klmh. The interviewees will likely not know the weight of the candles that they use for lighting, so the field supervisor would have to weigh the various candles sold in the community in a local store or market to determine the precise weight for each size.

For candles, obtain the following information:

- How many candles are used per time period (day, week, or month)?
- How much does each candle cost (US$/candle)?
- How much does one candle weigh (kg/candle)?
- How many klmh of lighting are obtained by each kg of candle (klmh/kg)?

With the information gathered from the questions above, we can calculate the Pa (price of candles in $/klmh) and Qa (consumption of candles in klmh/month).

For kerosene, obtain the following information:

- How many liters of kerosene are used per time period (week or month)?
- How much does each liter cost (US$/liter)?
- How many klmh of lighting are obtained per liter of kerosene (klmh/liter)?

With the exception of the final question in each set above, for both candles and kerosene all of the above data would be acquired through a household questionnaire. Data on the lighting value of various sources, including candles and kerosene, are obtainable through detailed academic studies.[5]

[5]See van der Plas and de Graaff, op. cit.

With field experience, the practitioner will come to realize that candles of different sizes are used in most rural areas of developing countries, so the questionnaire must be adapted to include all sizes. On the other hand, not all rural households use candles. The researcher can therefore save time by asking one question at the beginning of the section on lighting, for example: Do you use candles for lighting? If the interviewee provides a negative response, then you can skip to the next series of questions. A similar interrogatory framework applies for other traditional lighting fuels, such as kerosene for lamps.

After identifying the specific information required for project analysis, it is possible to define the variables, formulate the questionnaire, and then design the database to store and analyze the data to be collected.

One way to define questionnaire data variables for the corresponding database is by assigning acronyms from the words that describe the variables, such as:

- EWTP = Expressed Willingness to pay for electric service

- RWTP = Revealed Willingness to pay for electric service

Alternatively, one can assign names to variables according to the corresponding number on the questionnaire. For example, in the questionnaire for the CEF project, question 407 of the survey instrument related to expressed willingness to pay. This question was posed in the form of a bidding process, in which the interviewee would make a first offer and then the researcherr would raise the monthly cost up to a point at which the interviewee would no longer be willing to pay more for electric service. The final bid was then converted into U.S. dollars according to the prevailing exchange rate on the date of the survey. The variables used in the CEF database for these two questions were the following:

- Q4071ST = Question 407 the first offer in the expressed WtP auction

- Q4072ND = Question 407 the second (last) offer in the expressed WtP auction

To determine revealed WtP, one would add up all of the expenditures for all the alternative energy sources used for lighting and appliances for which electricity would immediately subsititute. As previously mentioned, we can assign names for the specific variables with letters taken from their names as follows:

- SCQT = Small candles, quantity/month

- SCP = Small candles, price

- SCCM= Small candles, cost/month = SCQT * SCP

Alternatively, the variables can follow the sequence of the questions on the survey instrument. For the CEF project, the question concerning small candles was No. 201. The designation for such variables in the CEF database was:

- Q201SC = Question 201 Small candles, quantity/month

- Q201SC1 = Question 201 Small candles, price

- Q201SC2 = Question 201 Small candles, cost/month = Q201SC * Q201SC1

In addition to the data requirements, it is also often important to obtain more subjective information by asking simple questions concerning the opinions held by the population. Examples include:

- *System technology.* What opinion do you have concerning electric meters? Do you trust that the meters are accurate?

- *Stakeholders and counterparts.* Who are the most respected leaders in your community, and who can be counted on to assist us in executing the project?

After identifying the specific information required for project analysis, it is possible to define the variables, formulate the questionnaire, and then design the database to store and analyze the data to be collected.

- *Public awareness.* What is your preference for receiving information about the project (radio, TV, newspaper, community meetings, or other means of communication)?

- *Institutional model.* Do you prefer a cooperative, government, or private institutional structure?

Designing and Testing the Questionnaire

A good questionnaire design not only prevents problems of interpretation and facilitates the flow of the interview, but also serves as a guide for the design of the database

After formulating the survey questions, organize them into a physical instrument. A written questionnaire records household information and data in an easy, efficient, and rigorous manner. A questionnaire not only provides a physical record of information gathered though field interviews, but also facilitates the transfer of the information to an electronic database for reporting and analysis. A good questionnaire design not only prevents problems of interpretation and facilitates the flow of the interview, but also serves as a guide for the design of the database and rapid transfer of printed information to the database itself.

The role of the enumerator, or interviewer, is to quickly and efficiently obtain information from the interviewee. The questionnaire acts as a guide for this process, and therefore must follow a logical, simple and direct format. With a well-designed questionnaire, the enumerator can write down the information quickly and conduct more interviews, while also preventing errors and confusion when the information is later processed. The information recorded in the questionnaire determines the quality of the WtP and the economic benefit analysis.

One basic survey design is the following:

- *General information.* The questionnaire begins with questions concerning general information, such as the type of consumer (residential commercial, or industrial), and other specific details such as number of individuals in the household, or type of productive use (mill, carpentry, store, etc.)

- *Information related to lighting.* To determine the Revealed WtP of the consumer, the questionnaire includes questions concerning the use of and expenditures on all types of alternative energy sources for lighting. This section includes questions concerning the use and size of candles, type and amount of fuel for traditional lamps, the type and amount of batteries used for flashlights, the use of solar panels, etc.

- *Information concerning other uses of energy.* This section of the questionnaire contains inquires regarding usage of alternative energy sources for household electrical appliances, such as car batteries that might be used to power radios and televisions. It may also include data on the consumption and cost of diesel fuel or gasoline for private electricity generators.

- *Expressed willingness to pay:* Normally this section of the questionnaire starts with a hypothetical scenario in which the interviewer asks the potential consumer how much he or she is willing to pay for a reliable and safe electric service and, through an auction/bidding process, determines the maximum amount that a consumer would express as their WtP for electrical service. A later section of this module goes into more detail on the proper method of conducting the auction/bidding process.

- *Consumption and cost of electricity.* To compare alternative energy sources and electricity, it is crucial to obtain information concerning consumption and cost of electricity. The section of the questionnaire containing questions related to electricity is for those consumers who currently have access to electric service, either in the target area of the project or in a similar socio-economic area. This information helps analysts estimate the consumption and cost of electricity for new consumers. It is also a key factor in estimating the potential demand for electricity from the project. In addition to data on consumption and cost of electricity, record consumer opinions on their current electric service and their perception of the quality of that service. In some systems, the consumer has a meter that bases their monthly bill on actual consumption. In other cases, the consumers do not have a meter, or the meter is broken, and they pay a fixed amount measured by "point loads" within the house, which normally are light bulbs or plugs. Another important aspect of the analysis of electricity consumption is its use within the home. Normally a home has several light bulbs for lighting, and depending upon the socio-economic level of the family, there might also be daily-use household electrical appliances, such as fans, irons, or a television set.

- *Income and expenses.* Data on the consumer's income and household expenditures allows the project team to calculate monthly household energy expenditures as a percentage of total monthly expenditures. In the majority of the rural areas where electrification projects take place, consumers maintain a fragile economic equilibrium that mostly depends on the harvest and sale of their agricultural products. Many try to supplement their agricultural income with other types of work, such as manual labor, or they receive income from family members that have steady jobs in a town, city, or foreign country.

- *Participation and disposition toward community organizations.* For electrification project planners contemplating some form of community-based or cooperative framework, it is useful to analyze and verify the presence of existing community organizations/cooperatives in the community, the level of participation of the consumers in these organizations, and their disposition towards these organizations as providers of the service.

In the case of the Tomoyo project, the demographic group leader designed the questionnaire using an examplar questionnaire that NRECA had formulated for other similar studies in Latin America. The team went over the questionnaire thoroughly and made adjustments to incorporate local terminology, the Bolivian currency, and other corresponding variables. Among other changes, they eliminated turpentine as a lamp fuel because it is not used in Bolivia, and substituted "wick" for the term "wick lamp."

Once the questionnaire is complete, it should be field tested. Although this could include trial field surveys in the project area, location is not critical in evaluating the instrument itself. No matter where it is tested, the draft questionnaire must be vetted to determine whether the questions that are posed are understood by interviewees, and to make sure it includes all the forms of energy that are used by the target population. The project team leader and staff should evaluate the questionnaire and make revisions based on information learned in the initial field trial before using it as part of a formal survey.

The draft questionnaire must be vetted to determine whether the questions that are posed are understood by interviewees, and to make sure it includes all the forms of energy that are used by the target population.

Designing the Database

Once the revisions of the survey questionnaire are complete, it can serve as the basis for the design of the electronic database that will compile the information recorded in the field survey. Carefully considering the information processing methods employed during the data entry phase contributes to the logical and simple organization of the database. Modifications to the design of the database based on changes to the questionnaire implemented while the field survey is in progress are permissible. For greatest efficiency, finalize the initial design prior to the commencement of field surveys, so as to speed up the process of transferring the questionnaire information to the database.

If the person designing the database has enough experience in database design, then he or she may proceed with the design. If not, the project team must hire external experts for the task. NRECA has used both options.

There are several types of software available for data management and reporting, and, in some cases, analysis. A common database program is Microsoft Access, which is part of the MS Office suite of software programs. Access can manage high volumes of data from multiple projects, as well as only a small data set from a limited field survey sample. Other software options worth considering include Epi Info, SPSS, or Microsoft Excel (for very small survey sample sizes), among others.[6]

The database for the Tomoyo project was designed in Excel because the sample included only 65 surveys. Normally such a database would be assembled in Access, Epi Info, SPSS, or another similar program.

Defining the Targeted Population

It is important to define the target population for the survey carefully, so that the fieldwork collects representative results from the population in the proposed project area. The target population for the survey is generally the population of the electrification project. However, surveys may sometimes be conducted within populations that already have access to electricity but fall outside of the proposed project to estimate potential electricity consumption and expenditures among consumers within the project area.

[6]Epi Info is a free statistics package developed by the Center for Disease Control (CDC) of the United States.

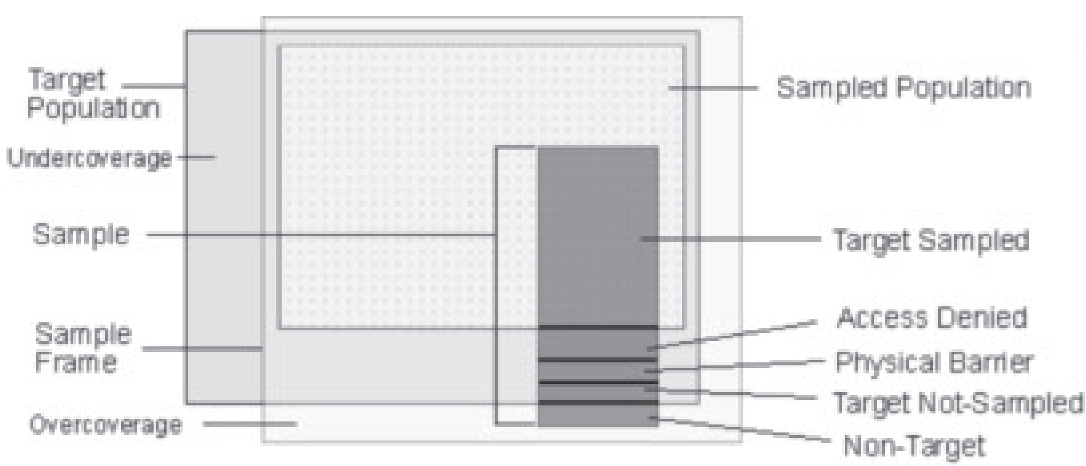
For the CEF project, the target population was all potential consumers who lived within the proposed area of service of the cooperative at the time the survey was conducted. Demographic data from the most recent census indicated that more than 21,000 families lived in the proposed project area. Not only would it have been very expensive to interview each of the 21,000 families, this is not actually necessary. To obtain data that is statistically representative, it is only necessary to interview a sample of the total population. Illustrated below is the sample frame for a survey, that is, a physical representation of the target population.

The relationship among the target population, the sample frame, and the sample can be appreciated graphically in Figure 2.

Setting a Sample Frame/Producing a Map of the Project Area

When electrifying small project areas, it is feasible to create a list, or map, of all potential consumers. However, for larger projects, such as the CEF, this data not only may not be available at the level of detail required, it would be too costly to obtain. Because the consumer survey generally covers the entire proposed area related to the scope of the proposed electric service, a general map can be used that does not go down to the level of households. Figure 3 shows the general map of

Figure 2. Relationship among the target population, sample frame, and the sample



Source: U.S. Environmental Protection Agency the proposed cooperative concession area that was used as the sample frame for the CEF project.

Figure 3 illustrates the extension of the proposed electrification lines of the CEF project. The project included locations in eight municipalities west of San Juan de la Maguana, from Pedro Corto in the east, up to the border with Haiti in the west, and from Pedro Santana in the north to Batista in the south.

A GIS was used to prepare the maps that are presented in this section. The target population can be subdivided using the GIS according to the criteria considered necessary or practical for the survey. For an electricfication project in northwestern Uganda, the city of Arua was divided into seven specific zones, which encompassed areas with and without access to electricity, as well as a wide range of socioeconomic levels. The GIS helped subdivide area into the houses located in the city center, houses located 300 meters or less from the distribution grid, and communities more than 300 meters away from the grid. Surveys were conducted in eight different locations that represented a broad sample of socioeconomic conditions within the surveyed area. The black points shown in Figure 4 indicate the communities where household surveys were conducted.

Determining the Size of the Sample

The next step in the design of the survey consists in determining the size of the sample. The analyst must specify three key criteria to select an adequate sample size: the level of precision, the level of reliability, and the degree of variability.

The target population for the survey is generally the population of the electrification project.

Level of Precision

The level of precision, also called sample error or interval of reliability, is frequently expressed in percentage points. If a survey shows that 62% of the interviewees are in favor of a proposal, and the sample error was + or – 5%, then it could be concluded that in the entire population of the proposed area 57% to 67% of the population were in favor of the proposal.

Figure 3. Service area of the CEF project

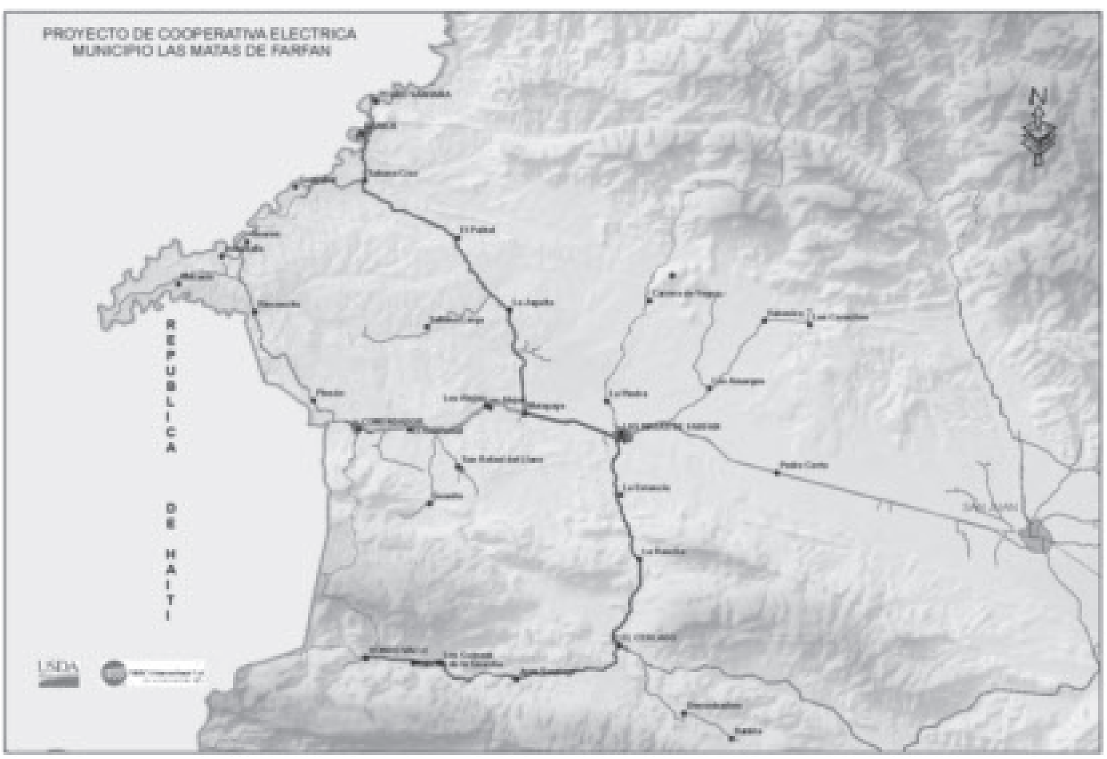
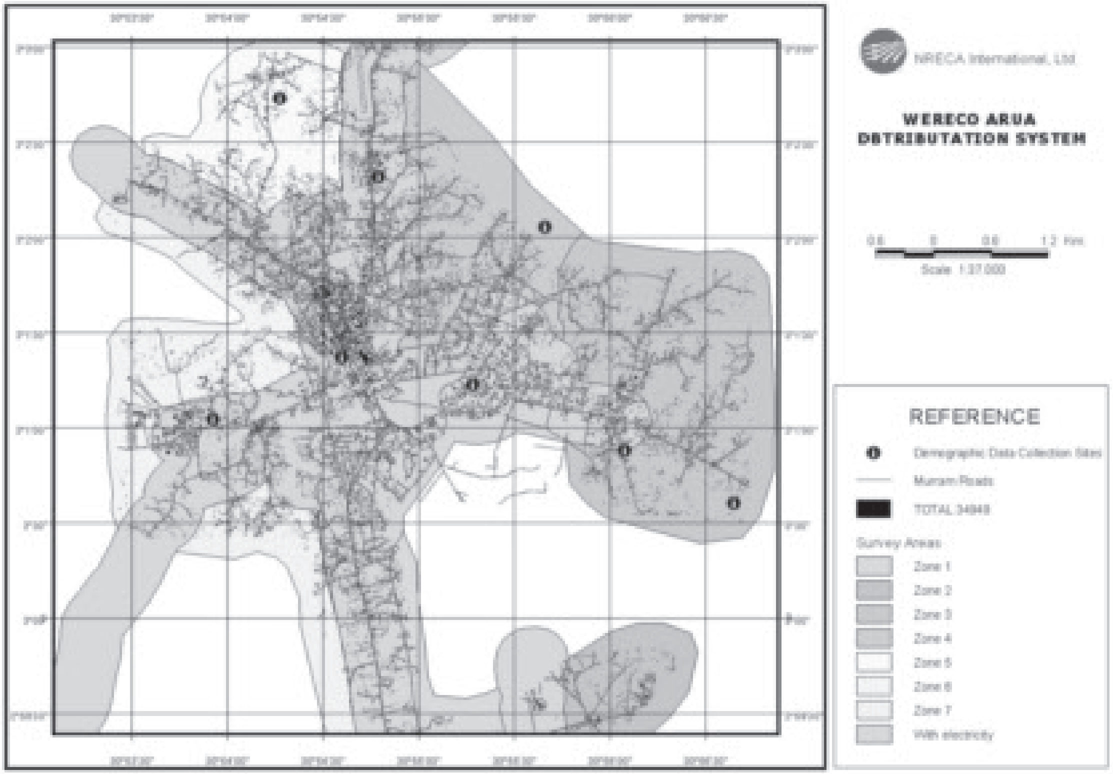


Figure 4. Map of surveyed area for the city of Arua, Uganda



The analyst must specify three key criteria to select an adequate sample size: the level of precision, the level of reliability, and the degree of variability.

Level of Reliability

The level of reliability indicates the degree of certainty of the results based on the principles from the Central Limit Theorem, which is the second fundamental theorem of probability. It states that the sum of a large number of independent and identically-distributed random variables will be approximately normally distributed (i.e., following a Gaussian distribution, or bell-shaped curve) if the random variables have a finite variance. Formally, a central limit theorem is any of a set of weak-convergence results in probability theory. In simple terms, a level of reliability of 95% means that 95 out of 100 samples reflect the real value of the population.

Degree of Variability

The degree of variability refers to the distribution of the population's attributes. The greater the variability, the larger the sample required. If the population is more homogeneous, then the sample can be smaller. A proportion of 50% indicates maximum variability. Thus, if the actual degree of variability is unknown, a conservative value of 50% variability is used to determine the size of the sample.

Strategies to Determine the Size of the Sample

With smaller populations, such as less than 100 houses, field workers should survey the entire target population. This is based upon two justifications. First, the main cost to conduct a survey is not the marginal cost of conducting a few additional surveys. Rather, the main costs are those associated with the design and preparation of the questionnaire, transporting the enumerating team to the field, and the data processing and analysis. Second, smaller populations require samples that include the majority of the population to obtain an acceptable level of precision. The formulas indicate that for a population of 100, a sample of

80 is needed for a level of reliability of 95%, an interval of reliability of + or – 5%, with a degree of variability of 50%. If the target population is of 100 or less, we therefore recommend interviewing everyone available. The cost of completing a few additional questionnaires is not significant, and the additional questionnaires help ensure a statistically valid analysis.

Another strategy to determine the sample size is to use the sample size used for similar studies. This approach is valid as long as the conditions are substantially similar and the previous study was statistically valid.

A third option is using published charts detailing valid sample sizes. There are charts available that have been prepared using formulas regarding valid samples sizes for various population sizes. To use such charts correctly, the user must fully understand the predetermined parameters upon which the charts were prepared.

Finally, several sample size-determining formulas exist. Equation 3 shows one such formula.

Equation 3. Formula to determine sample size of a large population of unknown total amount

ss = (Z^2*(p)*(1-p))/c^2

Where: ss = sample size

Z = Z value (for example: 1.96 for a level of reliability of 95%)

p = percentage that selects a response, expressed in decimals (.5 is the most conservative value)

c = interval of reliability, expressed in decimals (For example: .04 = ±4)

For example, when conducting a survey for an unknown population size with a level of reliability of 95%, and a level of precision of ±5%, calculation of the size of the sample is as follows.

ss = (1.96^2*(.5)*(1-.5))/.05^2 = 384

With a level of precision of 6%, instead of 5%, the size of the sample for an unlimited population size is 267.

In practice, NRECA has used a sample size of 300 for many surveys. A sample size of 300 is applicable for a maximum population of 1,376 people at a level of reliability of 95%, an interval of reliability of 5%, and a maximum degree of variability of 50%. However, if an interval of reliability of 5.66% is used instead of 5%, then a sample of 300 can be used for an unlimited population size. If the interval of reliability is maintained at 5% for a population of 100,000 or more, then a sample of 384 to 400 is needed, depending on the formula applied.

A sample size of 300 was determined for the CEF project. As mentioned above, for an unlimited population size, this results in a level of reliability of 95% with an interval of reliability of 5.66% with a degree of variability of 50%. To obtain at least 300 valid interviews, it is important to conduct at least 15-30 additional interviews beyond 300 to account for interview errors and other potential data faults. The final number of valid interviews processed for the CEF project was 302.

Selecting the Sample

The selection of the sample population is as important as the selection of the final size of the sample. The following example illustrates this point. Suppose we want to conduct a survey in a region of a country, and it has been determined that the size of the sample must be 300. If the field workers conduct all 300 interviews in the richest area of the most prosperous city of the region, then the results from the interview would not be representative of the entire region, even if 300 questionnaires were completed.

Some Sampling Methods

The methods for selecting a sample population so that it is scientifically representative of the target population interviewed include pure random samples and cluster or stratified sampling.

Many of the mathematical theorems concerning the discipline of statistics base their theories and methodologies on consequent suppositions within a randomly chosen sample. By definition, in a randomly selected sample each individual from the target population has the same probability of selection. When conducting field surveys for electrification projects it is often not practical, and in some cases it is impossible, to construct a randomly selected sample.

With smaller populations, such as less than 100 houses, field workers should survey the entire target population.

The CEF project used cluster sampling, in which the population is divided into groups and the groups are selected randomly. The groups in this case were the political divisions called "sites." Knowing that the project would benefit the greater population, all the sites of 200 houses or more were selected, along with a randomly selected sample of small sites. To obtain 300 surveys from the total population of the sample, it was necessary to interview an average of one out of every 43 houses. For the surveys in each site, the field worker would go to a central location in the community and select a random house for the first interview. After the first interview, the interviewer would advance 43 houses for the next interview. If no one was home or if the person did not wish to be interviewed, the researcher would go on to the next house.

If you know or suspect the existence of subgroups with very different circumstances or behaviors, then to preserve statistically representative conclusions, it is necessary to conduct a stratified sample. For example, this might apply if you wish to find the difference between those who receive an electric service with meters and those who receive electric service without meters.

In an electrification project's base case, where the communities have not had access to electricity previously, it is appropriate to conduct a random sample comprising of 300 surveys of non-electrified households. To obtain data on households that have electric service, the analyst must conduct another random sample of 300 surveys in a community with similar socioeconomic conditions. These two sample populations should not be mixed. For the CEF project, the target population had access to electric service but with frequent and prolonged blackouts. Under these circumstances, only 300 surveys were conducted because no nearby communities existed that experienced a similar lack of reliable and uninterrupted electric service.

Defining the Field Procedure for the Sample

After defining the target population, determining the sample size, and selecting the sampling method, it is time to define the method of selecting each house to sample. In the Uganda project highlighted in Figure 4, it was determined that there were approximately 35,000 inhabitants within Arua, Uganda. Demographic data indicated that each household comprised an average of six people, adding up to approximately 6,000 households within the target population. Thus, if the population of the survey consisted of 6,000 houses, and the size of the sample was to be 300, then the team had to analyze one out of every 20 houses in the population of Arua.

Tools such as GPS and GIS-based maps facilitate the selection process. These tools can define the number and location of houses in each area, and they can be programmed to select, according to pre-determined calculations, the house where an interview should be conducted. Thus, the analyst can avoid any prejudices or preferences in the field that may affect the results of the survey. Where there are no satellite maps to illustrate household-level detail, a standard print map of the area, together with demographic data (preferably from an official census), can be used in selecting households for interviews.

After determining a statistically valid method of household selection, begin conducting the field surveys by starting at a strategic point, such as the main plaza of the community and counting the houses one by one to determine which should be subject to an interview. For example, to conduct 25 interviews in a community that, according to the census, contains 462 houses, first randomly select a number between 1 and 19. Hypothetically, if the number 4 is selected then the enumerator would start conducting interviews begining with the fourth house and would then count 19 houses before knocking on the door to conduct another interview. If the owners of the house are not there, then the enumerator should simply proceed to the next house.

Because the communities that formed part of the Tomoyo project were very small, it was easy to select the sample. Each community was divided into different zones, and one member of the team conducted interviews in each zone. For example, a community of 80 houses was divided into four zones roughly equal in size. Within each zone, two or three interviews were conducted, with the houses in each zone selected at random.

Selecting and Training Field Workers

The field workers, or enumerators, are the ones who record the information provided by the interviewee onto the questionnaire. For the integrity of the data, qualified and competent enumerators must conduct the fieldwork.

When selecting enumerators, consider their previous experience in censuses and surveys, fluency in the language(s) spoken by the target population, clear penmanship, and willingness to travel and stay at the field location for extended periods of time, often under difficult conditions. Depending on the local culture and customs, the interviewing team should include both men and women. Often, suitable candidates arise through recommendations from the national state census agency, or via other academic institutions and non-governmental organizations that conduct surveys for their own purposes.

Clearly present all details regarding salary, travel expenses, and transportation to potential candidates during the interview process, as well as in any formal contract for services. In some cases, the enumerators receive pay for each questionnaire completed, and in others, they may recieve a daily rate for their work. An expert supervisor can determine which method is most convenient and suitable, given the circumstances.

During the preliminary selection of enumerators, include one or two individuals more than the amount estimated to be necessary to complete the work. The final selection of enumerators proceeds after observing how these individuals respond to the training and practice interview. It is always a good idea to maintain contact with least two alternate enumerators in case one or more of the selected candidates is not able or willing to participate.

It is important to adjust the training of the enumerators to the level of their previous experience. Fully review the questionnaire in at least one training session. During this session, the supervisor must ensure that all enumerators comply with the basic requirements needed to complete the work. Ask for feedback to ensure that the candidates understand the concepts and the vocabulary of the questionnaire. This feedback is also useful in setting the level of vocabulary used in the questionnaire for the target area. The training must include instructions on how to formulate questions in a direct and impartial manner. Bias on the part of the interviewer can greatly affect the responses they receive from their questions.

The questionnaires intended for communities that already have access to electric service contain specific details that are different from those for communities without electric service. What differs is a question concerning the consumption and cost of electricity. The enumerator should courteously request the respondent's last three electric bill statements in order to provide a verifiable record of past consumption and expenditures, rather than simply rely on consumers' memories for the same information. Be aware that a significant consumption variation could exist in regions with

If you know or suspect the existence of subgroups with very different circumstances or behaviors, then to preserve statistically representative conclusions, it is necessary to conduct a stratified sample.

a marked difference between the summer and winter seasons of the year. The enumerator must have the necessary training to be able to interpret electric bills and record the most significant data onto the questionnaire.

After completion of the design of the questionnaire and the theory portion of the training, the enumerators must conduct a field test. The field test helps project managers detect errors in the questionnaire or parts of it that are not clear. In addition, the field test demonstrates the enumerators' ability to perform the job.

It is not always convenient to conduct a field test in the proposed project area. If the cost of field testing is too high, the project planners may choose to perform the field test in a local area, or even in the training room. In this method, each enumerator is responsible for completing a trial questionnaire, preferably by interviewing a person who has never seen the questionnaire. This is not as effective as conducting the test in the field, but it can still provide useful results. The supervisors must pay special attention to the manner in which the enumerators conduct the interview, either in the training room or in the field, to evaluate their competence for the job. After the field test, managers modify the questionnaire and make the final selection of the enumerators.

For the CEF project, NRECA hired an expert in household energy surveys who had conducted similar studies for NRECA in the Dominican Republic. This field survey expert selected and supervised the enumerators conducting the field surveys.

Conducting and Supervising the Interview

Previous Preparations for the Field Work

Before conducting field work, project planners must interview and select suitable candidates to serve as field enumerators, prepare all of the materials required to execute the survey, and define the logistical details. The logistics make it possible for the field work to be organized and conducted within the time frame and budget established for the project.

Preparing the Materials

The survey supervisor is responsible for ensuring that all required materials are in order and ready to take to the field. These materials include an adequate number of questionnaires, pens, clipboards (so that the enumerators can write on the questionnaire), and paper or notebooks for taking notes.

The field survey supervisor should assemble and have ready at least 10% more than the minimum required quantity of questionnaires, so as to compensate for errors in printing or transcribing data. For example, if the sample size is 300 then there should be at least 330 photocopies of the questionnaire. Enumerators should always receive extra writing instruments to ensure that time is not lost while conducting interviews.

Provide the enumerators with some form of credential or documentation, such as a badge or hat, which identifies them with the organization conducting the interview. Do this only if it does not influence the results of the interview.

Prepare a list of equipment and materials for the entire survey group and for each individual. The equipment and materials may include maps, compasses, a GPS, a first-aid kit, communication equipment, sun block, mosquito repellant, umbrellas, a lantern, a pocketknife, and a camera. Besides the minimum materials required to conduct the interview, the field survey supervisor must ensure that enumerators are prepared for the circumstances they will encounter. For example, when conducting field work in a very remote area, it is important to take along enough food and water.

Logistics

The level of logistical complexity required depends on the location of the target population and the sample size. The location affects transportation needs and the time required to get to each sampled household. The size of the sample affects the number of enumerators needed to complete the work in the time frame indicated.

If all enumerators live in the city where their interview will be conducted, then transportation arrangements could be as simple as telling each enumerator where and when to show up to set out to conduct the interviews. On the other hand, if the project area is very remote, it will be necessary to coordinate one or more transportation options, such as plane, bus, 4-wheel drive vehicle, boat, or motorcycle.

In the past five years, NRECA has developed a standard methodology for conducting interviews with a size sample of 300 surveys. Questionnaires vary in scope and number of pages, but six to eight pages is common. Typically, completing a standard questionnaire takes 20 to 30 minutes. Add additional minutes for the time required in a certain community to advance from one interview to the next. On average, an enumerator can complete 12 questionnaires in one day. Five or six enumerators, with a supervisor, can usually conduct 300 interviews in five days. If the proposed project is in a remote area, additional time is required to arrive at the site of the project and then return to the base or main city.

One key aspect of logistics planning concerns funds or money management. Money is required for travel and other expenses, and it is important to purchase and account for all necessary equipment or materials required to complete the field work in a timely manner. Depending on the circumstances, it might be best to give the travel expenses to the field workers on the first day or leave this duty to the supervisors. Determine whether the field supervisor will have to carry cash or will be able to go to bank branches or other financial institutions for cash withdrawls.

Field Work

The design process of the interview and the preparation of questionnarie materials culminate with the field work itself. If the enumerators are sufficiently motivated, and conduct their work in an efficient manner, the quality of the data and thus the analysis will be much higher.

Completing the Questionnaire

The process of filling out the questionnaire can appear simple and easy. Even though the design of the questionnaire helps the enumerator conduct the interview, there are many opportunities for mistakes when recording response information. Each interviewer has his or her own way of writing, and in some cases, the questionnaire uses a language they are less familiar with. The enumerator also has the difficult task of trying to maintain the flow of conversation over the course of the interview, while recording the data and responses given by the interviewee. It is essential to emphasize the importance of extreme care while recording the data obtained during the interview.

After completion of the design of the questionnaire and the theory portion of the training, the enumerators must conduct a field test.

Enumerators must use clear penmanship that is easy to read. With predetermined codes and shorthand, the enumerators may avoid having to write as much text. For example, instead of writing “four liters per day”, it would be faster and to record “4 l/d”. It is also vital that the enumerator write down the interviewee’s actual response and avoid the temptation of performing mental calculations to convert the data, for example electricity consumption over time. Finally, it is important to take physical care of the questionnaires so that they are not lost, damaged, or destroyed. The response information is useful only after it has been properly recorded on the questionnaire and entered into the database.

Tasks of the Field Supervisor

The field supervisor has several key responsibilities throughout the field survey process. For instance, the supervisor serves as director of the team of field workers. In this role, he or she is directly responsible for ensuring good performance by motivating the team to work in an efficient, responsible, and rigorous manner.

The supervisor must establish a solid professional working relationship with the research team, based on mutual respect and trust. The supervisor can improve performance and motivation by establishing an esprit de corps, which emphasizes the importance of their work for the project and acknowledges their effort and diligence at the end of each day when the day's goals have been achieved.

The supervisor must review the completed questionnaires each night to ensure that the enumerators are completing the questionnaires correctly, that the information recorded is legible, and to clarify any discrepancies.

The field supervisor must accompany each enumerator at least once to review the way in which he or she conducts the interview. The supervisor must also meet with the enumerators as a group or individually to review the questionnaire, clarify any questions they might have, and respond to comments from the enumerators on any topic related to the field work. The supervisor must review the completed questionnaires each night to ensure that the enumerators are completing the questionnaires correctly, that the information recorded is legible, and to clarify any discrepancies.

While surveying the community, the supervisor must take systematic notes concerning general infrastructure and development, such as home construction, the local economy (commercial activity, agricultural products, etc.), and road quality and distance from other communities. It is also the responsibility of the supervisor to ensure that someone visits local stores or marketplaces to verify the local measurements and prices of alternative energy sources. For example, the supervisor must find a well-calibrated scale to determine and record the weight of the different available candle sizes. In addition, the supervisor must investigate whether the local custom is to use uncommon units of measurement, such as "bottles" or "cans" instead of liters or gallons. Otherwise, the enumerators may not be recording one "bottle" of kerosene as a liter without verifying how much kerosene is actually in a bottle of that size.

Interviews with Leaders of the Community

While the enumerators conduct their surveys within the assigned community, the supervisor must locate and meet with the local community leaders (mayor, council-member, sheikh, or village elders). During these meetings, the supervisor must clearly explain the purpose of the survey and their duration within their community. In small communities, the supervisor must often request the support and help of the local leaders to encourage the community to participate with the survey and enumerators. Besides explaining the project, the supervisor must conduct a survey of the community with the local leaders to acquire information concerning the local economy, migration patterns, productive uses of electricity (active or latent), community organizations, public services (schools, health clinics, etc.), and other relevant information.

Residential Interviews

For most rural electrification projects, the majority of interviews conducted on energy use and WtP involve community members. The supervisor and the enumerators must consider the times during which key individuals will be available for interview. For example, in many rural areas, farmers leave early in the morning to tend to their crops, while in more urbanized areas people will leave for their jobs later in the morning. Thus, during normal business hours many people will not be at home, and the supervisor must adjust the survey work schedule accordingly.

The start of the residential interview process begins at the respondent's door when the enumerator greets the residents and asks permission to enter their property or their home. After entering, the enumerator must greet and/or introduce themselves again, showing respect in a manner that is locally accepted (for example, with a verbal greeting of gratitude, hand signal, handshake, etc.). The enumerator must provide a clear and brief introduction of the project and explain the purpose of the interview. The enumerator should emphasize that there is still no commitment to complete the project, and that the decision to implement a project would depend greatly on the data acquired during the various interviews conducted within the community. The enumerator must never provide false expectations, regardless of the data that might encourage.

The interviewer should then answer any questions that the interviewee might have, then initiate the interview. For the section concerning lighting with alternative energy sources, the enumerator must request to see the candles and lamps used and the typical container used to store fuel such as kerosene. If the home utilizes solar panels, the enumerator must record the brand name, capacity, the number of modules, and the number and type of batteries used within the system. Concerning the use of energy for household electrical appliances, the enumerator must try to record the watts of power for each appliance. This information will determine their kWh consumed per month. If the household uses a private generator, then the enumerator must ask permission to inspect it. Then, he or she must fill in the corresponding section of the questionnaire regarding the generator's brand name, capacity, type of fuel used, cost of maintenance, the amount of hours per day during which it operates, and above all, the amount of fuel used per time period (e.g. 10 liters/week).

In the Expressed WtP section of the questionnaire, the enumerator should describe a scenario in which the household receives reliable and high quality electric service. Following this hypothetical scenario, the enumerator then seeks to determine by means of an auction or bidding strategy the maximum amount that the consumer would be willing to pay for such electric service. There are two ways of conducting the bidding. The enumerator can propose a maximum monthly price for the electric service. Then, the interviewee can accept the price, or if he or she refuses, the enumerator would lower the price in increments until the potential consumer accepts it and therefore indicates the price that he or she is willing to pay for electricity. Alternatively, the enumerator could start the "offer" at a very low monthly price and then increase the price until the interviewee closes the offer, indicating the maximum price that he or she would be willing to pay for electricity.

This same section of the questionnaire usually includes the Expressed WtP for the consumer's connection costs. In most rural electrification projects, the consumer pays for some or all of the connection costs to their house, which includes the cost of the meter, other related devices, and the physical installation of the service. The enumerator uses the same bidding or auction strategy described above to determine the maximum amount that the consumer would be willing to pay for a connection, either as a one-time payment or as a monthly fee, imposed over a defined period of time (e.g. US$3/month for 36 months).

For most rural electrification projects, the majority of interviews conducted on energy use and WtP involve community members and their homes.

To determine the consumer's income and expenditures in a clear and detailed manner, the enumerator must ask questions concerning several sources of income, such as agricultural products that are sold (including the amount and price received), and the typical expenditures of the family, such as food, school registration, clothing, transportation, etc. In many cases, consumers in rural areas purchase their food supply and essentials at traditional markets and weekly fairs. If the interviewee does not know the exact amount of the expenditures, then the enumerator could reach an estimate of their monthly expenditures by asking for the total expenditures for purchases at each fair.

If the house already has access to electricity, then the consumption and cost of electricity can be arrived at from the household's electric bills. The enumerator must try to examine at least three past monthly bills and record the data in the appropriate box of the questionnaire, keeping in mind any potential seasonal fluctuation in electricity consumption. The enumerator must also record the watts of power of all light bulbs (both incandescent and fluorescents) and household electrical appliances, and the number of hours per day that they are used.

Productive Use Interviews

Almost every community contains several types of energy consumers. Although the majority of consumers are households or residential users, small businesses and/or small industries are generally large consumers of energy. We call the latter types of energy uses "productive uses" because they consume energy to provide services or make products. A "productive use" is any use of electricity that generates income for the user, such as mills, stores, restaurants, sawmills, mechanical shops, and tire repair shops.

The enumerator must never provide false expectations, regardless of the data that might encourage.

The enumerators must receive training on how to identify productive uses and how to conduct productive use interviews. Whether through electricity or alternative energy sources, productive uses consume much more energy than does a typical residence. In addition, they provide a source of employment for the community and income for their owners and employees.

The interviews for productive use respondents follow the same format as a residential interview. However, field workers must understand the importance of recording the data related to fuel consumption and electricity. These data greatly influence the estimate of the potential demand for electricity and the potential income to the project. The enumerators must acquire reliable data about the equipment used for the different processes, and above all, the fuel consumption for any portable power generation units or other equipment in use.

Entering, Revising, and Tabulating Data

After the supervisor has verified the completed questionnaires, the data contained on the print version of the questionnaires are transferred to the database for processing, reporting, and analysis. This section how to enter, revise, and tabulate the compiled data from the questionnaires.

Completing and Cleaning the Database

This section describes the physical process of transferring data from the questionnaires to a computer database. However, we recommend that those in charge of handling the data keep up to date with the latest advances in automated data recording methods and equipment, such as equipment that reads the data directly from the questionnaire. As such equipment enters the market, it will help reduce the time necessary for data entry, as well as the number of errors in data transcription.

In some instances, one person might be able to complete the process of entering data. However, in most cases, it is helpful to have a team of at least two people. Regardless of the number of people involved in data transcription, there are certain steps required to transfer the data from the questionnaires to a computer database. These steps include:

- the organization of the questionnaires so that the data can be easily and efficiently transferred to the computer
- identifying and hiring one or more transcribers
- ensuring the availability of computers and adequate software
- the data entry process itself
- cleaning of the files
- making one or more back-up copies of the master document and other vital documents

The computers and software used for data entry must be compatible with the software used for data processing and analysis. One detail that could influence the efficiency of data entry is the design of a data entry file. A file programmed to detect errors and to skip automatically to the next field can speed up the data entry process.

Ideal transcribers are individuals who can enter the data quickly and without errors. The transcribers must receive training to know what to do when questions arise, when information is missing on the questionnaire, or when it is hard or impossible to read the response. For the CEF Project, NRECA hired transcribers, but for the Tomoyo project, given the small size of the sample, the local NRECA team entered the data. One member of the team read the information while another member entered the data into the Excel database.

The first step in data review and revision is to make sure the transcribers have verified all of the information entered. The contracts for transcribers could include fines for errors or simply state that they will not be paid unless the database contains no errors.

After entering all data from the questionnaires into the database, the supervisor must perform a detailed and systematic revision of the database. To verify the data, the supervisor can randomly select a percentage of the questionnaires to review. Then the supervisor would compare each entry in the database to the answer on the questionnaire. If the percentage of errors is greater than the minimum acceptable, then the entire database must be rejected, with the contractor or transcriber instructed to start the process of data entry again from the beginning. The CEF project had to follow this procedure.

After verifying that the information in the database exactly reflects the information recorded on the questionnaires, the supervisor must perform another level of revision. This task includes eliminating data that contain errors that are obviously out of the reasonable range of the dataset. Only an expert with the adequate experience required for this delicate task must do this. For example, the project manager might decide to eliminate an entry of 12,000 entered into the field that corresponds to a question regarding how many small candles a family uses per month. If the range of responses to this question in the rest of the database is between 2 and 100, 12,000 would clearly be an unrealistic response.

Data Processing

Once the entering of data into the database is complete, data processing begins. This involves applying formulas to obtain sums, averages, frequencies, percentages, etc. It might also involve programming the database to reorganize the data in an ascending or descending manner or presenting the data in a graph or table. The goal of reorganizing, categorizing, or processing the data is for an expert to analyze and to interpret the data and recommend actions according to the results of the analysis.

A "productive use" is any use of electricity that generates income for the user.

Sometimes the expert in charge of the interview performs all the data processing. Other times, he or she prepares detailed instructions for programmers to process the data, so as to obtain the necessary results for the next steps of the analysis. The analyst can study the results of the processing, look to see whether anomalies or outliers are present, and determine whether further assessment of the database is necessary.

Analyzing and Interpreting Data

The next phase of data analysis and interpretation is important because its results become inputs for the economic benefit analysis and financial projections, as well as providing estimates of the total demand of electricity in the project area.

The person who performs the data analysis and interpretation should ideally have a reasonable amount of experience and expertise gained from similar assignments. If the analyst does not have experience in data analysis and interpretation, he or she should work with an individual with experience in the matter until acquiring a minimum amount of experience.

It is important not to allow biases, preconceptions, or premature conclusions to influence the analysis. The Expressed WtP, for example, in theory reflects what a consumer would be willing to pay for the electric service. The analyst could infer that if the consumer understands what reliable electric service is, the consumer should logically be willing to pay more for electricity than what he or she pays for non-electrical energy sources. Nevertheless, this is not always the case.

The goal of reorganizing, categorizing, or processing the data is for an expert to analyze and to interpret the data and recommend actions according to the results of the analysis.

In some instances, consumers indicate that they would be willing to pay more than what they normally spend on alternative energy sources, while others respond to the enumerator's auction strategy by indicating they would be willing to pay less than what they currently spend for alternative energy sources. The latter response seems counter-intuitive, but it could indicate that either the consumer does not know exactly what he or she spends on alternative energy sources, does not understand the scenario described by the enumerator concerning the electric service, or simply does not value electric service as an important good or service.

If the results from the interviewees' Expressed WtP are less than the expenditures for alternative energy sources, then the strategies used for the interview must be reviewed, as well as how the enumerators described the electric service to the interviewees. On the other hand, if the Expressed WtP results are much higher than the Revealed WtP, the analyst must compare the Revealed WtP with the consumer's income. If the consumer indicates that he or she is willing to pay much more than what he or she presently spends on alternative energy sources, but the data on their income does not support such a WtP, then the analyst must consider the validity and applicability of the consumer's Expressed WtP. The consumer may clearly indicate the will and desire for electric service by indicating a high WtP, but based on his/her income there would be no way of ensuring payment for the service. The analyst must look for such results that are out of the range of feasible results, both for specific cases (individual consumers) as well as for the results in general. In cases where the answers do not make sense, the analyst must compare the data with the actual questionnaire and discuss it with the enumerator, if possible.

It is important to study the ranges of the results, starting with the Revealed WtP, and specifically with the expenditures and consumption of alternative energy sources used for lighting, to determine whether they are consistent with similar projects and known generalities.

Depending on the community's socioeconomic profile, the results of consumption and expenditures for alternative energy sources for other uses could reflect very low levels of consumption, such as in the Tomoyo project in Bolivia, or very high consumption, which occurs in parts of the Dominican Republic. Unless the interviewees are extremely poor, a majority of rural households typically have at least a small radio, used for basic entertainment and information. These radios use batteries of different sizes. Some use two type "AA" batteries, while a larger portable sound system could require the use of four to six of the largest size, type "D" batteries. The use of dry cell batteries normally represents a significant expense for the interviewees, both because they have a high cost per unit and because they do not last very long if they are used for powering a radio for several hours every day. In spite of their cost, frequently individuals are willing to buy dry cell batteries because they place a high value on entertainment and information. In economically marginal areas, there is typically little use of portable power generation units because very few people have the capital to purchase one, much less the income necessary to pay for fuel and maintenance.

Information concerning the consumer's income and expenditures can vary, especially in rural areas where the rural population consumes some or all of their agricultural harvest. In such cases, segregate agricultural product income from other sources of income, such as manual labor, sale of products, income received from family members in a foreign country (remittances), etc. The questionnaire also contains a list of all expenditures for products and services. The analyst must use the data related to income and expenditures cautiously, especially if there is evidence of a distortion of reality due to factors such as the following:

- The interviewees do not have a clear idea of what they earn or spend.
- They gave out wrong information or information that does not make sense.
- They refuse to give out information for any reason.

In such cases, the results must be purged and considered unreliable. When a consumer's reported income is high, confirm that the consumer's expenditures also correspond with this income. Generally, there is a direct relationship between income and expenditures for energy sources, and if the income is much higher than average, the expenditures are normally above the survey's average as well.

When attempting to record actual electricity consumption and expenditures from households that are already electrified, enumerators may find that the consumers do not have past electric bills available. If this occurs, results could be subject to distortions due to insufficient information. Another obstacle in the way of reliable results occurs where electriticity consumption is estimated rather than metered by the company that manages the distribution system. In such cases, it is essential that the analyst compare the consumption shown on the past electric bills with the consumption estimated by counting light bulbs, household electrical appliances, and hours of use. In this manner, it can be determined whether the estimated consumption shown on the electric bills is reliable or not.

The range of electricity consumption varies greatly according to the area in which interviews are conducted. For example, in marginal rural areas of Bolivia where the use of household electrical appliances is very low, an average consumption of 25-35 kWh/month is normal, while in rural areas that exhibit a higher socio-economic profile, as in the Dominican Republic, the average consumption is approximately 130 kWh/month.

For the Tomoyo project, the NRECA team leader analyzed the database to determine whether the data were far out of the established ranges and whether there were gross errors in transcription or other related problems. The team leader examined expenditures for different energy sources as well as total expenditures to determine consumer WtP for electricity. The data clearly indicated that the majority of the consumers had low incomes. It also indicated that the majority consumed kerosene for lighting, and had a portable radio to listen to the news and other programs. There were no other electrical appliances in use in these communities, nor were there any portable generation units.

It is important not to allow biases, preconceptions, or premature conclusions to influence the analysis.

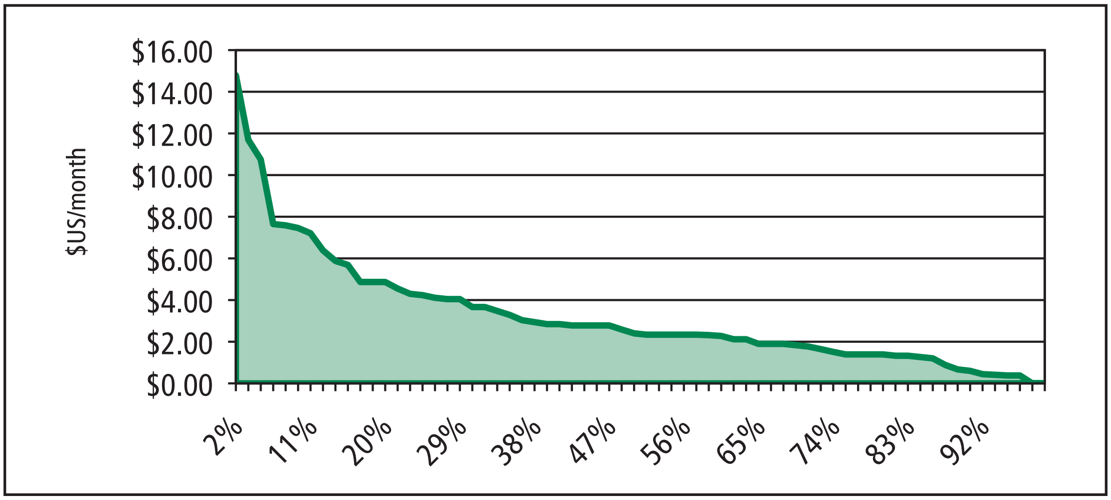
Calculating Willingness to Pay

The data concerning willingness to pay must be processed in such a way that the results can be presented not only as an average but also as distribution curves or charts with ranges.

Calculating Expressed WtP is as simple as applying the formula to obtain the average to all responses to the question of how much each person is willing to pay for the electric service. The CEF project had an average expressed WtP of US$ 7.63/month for the last offer from question 407. However, to better understand the economy of the target population it is useful to present the WtP results in the form of a distribution curve as observed in Figure 5 for the Tomoyo project.

To process the Revealed WtP data, the analyst concentrates on one energy source at a time, and converts it to a common unit of measurement, such as $/month spent for each energy source. Then the

Figure 5: Revealed WtP – Tomoyo Project



Generally, there is a direct relationship between income and expenditures for energy sources, and if the income is much higher than average, the expenditures are normally above the survey's average as well.

analyst can obtain the sum of all the expenditures for each energy source. Table 1 illustrates this procedure for small candle consumption within the CEF project. To begin, the amount of small candles used in each household was multiplied by what the interviewees indicated was the unit price per candle. Then, an average of the results was taken. On average, each household spent US$ 2.31/month on small candles, as indicated in Table 1. The analyst then calculates each other energy source in the same manner to obtain its expense per month. (Be careful not to multiply the average of the amount of an energy source by the average of its unit price. The result obtained from multiplying averages is not the same mathematically as the average expense calculated per household.) Figure 5 shows the Revealed WtP for the Tomoyo project.

Calculating Economic Benefits

In this section, we apply the basic theoretical concepts described earlier in this module to estimate the economic benefit of an electrification project. The first step is to add the economic benefit for lighting and the economic benefit for the energy consumed by electrical appliances. Then, to estimate the total economic benefit of the project, simply multiply the economic benefit of one average consumer by the total number of estimated consumers for the project. To express the economic benefit in terms of the scope of the project analysis, the net present value (NPV) of the benefit is calculated. The net present value is defined as the total present value of a time series of cash flows. It is a standard method for using the time value of money to appraise long-term projects. Used for capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows, in present value terms, once financing charges are met.

Taking the analysis one step further, the NPV of the economic benefit of the project indicates a limit to the acceptable level of subsidy for the implemention the project. In economic terms, there would be no point in implementing a project whose subsidy would be greater than the NPV of the total consumer economic benefit.

At a glance, calculating the economic benefit seems simple because the formula requires only the price and quantity of electricity (Pe and Qe), and the price and amount of alternative energy sources (Pa and Qa). However, the calculation usually becomes tedious because there are many alternative energy sources, and the data for each must go through processing and conversion. We now provide an explanation of how each variable is calculated.

Price of Electricity (Pe)

The electricity price for the CEF project was taken from the tariff specified by the government of the Dominican Republic when the financial analysis was performed. On that date, the electricity tariff for energy use was US$0.121/ kWh, with an additional fixed or demand charge of US$2.10/ month. Based on an average consumption of 133 kWh/month, this results in a tariff of US$0.137 /kWh. Dividing the tariff in US$/kWh by the conversion factor of 5 klmh/kWh for alternative sources of energy, the electricity price obtained was US$0.027/klmh.

Quantity of Electricity (Qe)

An estimate of the quantity of electricity (Qe) consumed by the average consumer can be obtained by gathering data on consumer demand for electricity in electrified communities that exhibit similar socio-economic profiles as the proposed project. The data compilation uses billing records from the electric company, consumer electric bills, and asking questions concerning the amount, watts of power, and hours of use for each energy source used for lighting, and for each electric device.

In the CEF project, data from the electric company showed average residential power consumption of 121 kWh/month and 408 kWh/month for commercial consumers.

For the CEF project, very few consumers were willing or able to provide their electric bills, so the enumerators relied on data provided by the type and use of lighting and appliances. Equation 4 illustrates how consumption was determined utilizing the basic data described above. For lighting, this included the sum of the multiplication of the watts of power of each energy source used for lighting by the daily hours of use (hours/day). The sum of all the energy sources used for lighting was multiplied by 30.4 days/ month and then divided by 1000 W/kW to obtain the kWh/month value consumed for lighting.

Equation 4. Calculation of power consumption for lighting

Lighting (kWh/month) = (((W1*H1) + (W2*H2) + …. + (Wn*Hn))*30.4)/1000

W1 = power in watts for lighting 1

H1 = hours per day used for lighting 1

30.4 = days/month (365 days/ 12 months)

1000 = conversion factor from watts to kW

On average, a rural household consumes 24 kWh/month for lighting. By multiplying 24 kWh/month by the lighting conversion factor of 5 klmh/kWh, results in a consumption of 120 klmh/month.

For household electrical appliances, each appliance was assigned a standard number of watts. For example, 80 watts were assigned to fans and 200 watts to standard television sets. These standard reference numbers were then multiplied by the hours of use for each appliance that the consumer indicated during their interview. The study assumed that refrigerators were plugged in all the time and assigned a standard consumption of 100kWh/month. For the CEF project, average household consumption of electricity for appliances was 109 kWh/month, and thus the total average residential power consumption amounted to133kWh/month.

To express the economic benefit in terms of the scope of the project analysis, the net present value (NPV) of the benefit is calculated.

Price of Alternative Energy Sources (Pa)

As shown in Table 1 above, for the CEF project the average expense for alternative energy sources for lighting was US$ 6.81/month. The same chart also indicated that the total klmh/month was 8.89. With these two data points, we were able to determine the cost per lighting unit simply by dividing US$6.81 by 8.89 klmh, and arriving at US$0.77/klmh.

The CEF project was exceptional because the potential beneficiaries of the project had

Table 1. Average expenditures for alternative energy sources (lighting only)

Energy Source	US$/month	Klmh/month	US$/klmh
Small candles	2.31	1.91	1.21
Medium-sized candles	2.22	1.91	1.16
Big candles	0.08	0.33	0.24
Small oil lamp	0.27	0.26	1.03
Medium-sized oil lamp	0.37	0.52	0.70
Big oil lamp	0.29	0.40	0.72
Kerosene lamp, tube	0.49	1.84	0.27
Kerosene lamp, wick	0.15	0.37	0.40
Kerosene lamp, pressure	0.01	0.30	0.04
Turpentine lamp, tube	0.32	0.99	0.32
Turpentine lamp, wick	0.01	0.02	0.47
Big batteries	0.21	0.02	8.61
Medium-sized batteries	0.07	0.01	5.80
AA batteries	0.02	0	16.00
Total	**6.81**	**8.89**	***0.77**

* Note: The last number is not a total. It is calculated by dividing 6.81 US$/month into 8.89 Klmh/month.

already benefited from an electric service, albeit with frequent and prolonged blackouts. The expenditures cited in the preceding paragraph were for alternative energy sources used during these blackouts. The lack of reliable electric service resulted in consumer consumption of both alternative energy sources (Pa), which means that actual consumer WtP and overall consumption of energy would have to include both Pe and Pa.

Let us assume a scenario in which an electric service provides an average of 18 hours/day of electricity. We further assume that for the remaining 6 hours without electricity, consumers use alternative energy sources, and the electricity outage is proportional over a 24-hour period. Then 18 kWh/month of electricity is obtained for lighting. Multiply the 18 kWh/month by 5klmh/kWh, resulting in 90 klmh/month of benefits. Add this figure to the 8.89 klmh of alternative energy to get 98.9 klmh/month. Distributing the fixed electricity rate to a lower amount of kWh makes the average cost increase to US$ 0.14/kWh, which multiplied by the 18 kWh results in US$2.53. The surveyed population thus would obtain a total of 98.9 klmh/month at a cost of US$9.34, resulting in a value price (Pa) of US$0.094/klmh.

Quantity of Alternative Energy Sources (Qa)

As described above, the Qa for the CEF project was 98.9 klmh/month.

The data shown in Table 2 were inserted into Equation 1 to calculate an estimated economic benefit for an average residential customer of US$7.34/month. The NPV calculation assumes a time period of 20 years and an 8% interest rate. Therefore, the NPV of this benefit is approximately US$865 per consumer.

To estimate the economic benefit of the energy consumed for operating electric appliances, one must subtract the electricity consumption used for lighting from the total consumption. The average consumption, calculated from the CEF project survey, was 133kWh/month. This estimated what

Table 2. Summary of variables needed to calculate the economic benefit for lighting (CEF project)

Variable	Description	Unit	Value
Pe	Price of electricity	US$/klmh	0.027
Pa	Price of Alternative Energy Sources	US$/klmh	0.094
Qe	Quantity of electricity	Klmh/month	120
Qa	Quantity of Alternative Energy Sources	Klmh/month	98.9

the consumer would use if they had electricity 24 hours a day. With electricity service for only 18 hours/day there was an estimated unsatisfied demand of 25kWh/month, of which 6 kWh was for lighting and 19 additional kWh for other uses. Multiplying 19 kWh/month by US$0.140/kWh results in US$2.66/month; added to the economic benefit for lighting of US$7.34, that renders a total of US$10.00/month and a NPV, at 20 years and an 8% interest rate, of approximately US$1,179.

For the Tomoyo project, energy consumption data recorded for the community of Potolo indicated an average residential consumption of 18.5 kWh/month for lighting, at a cost of approximately 15 Bolivianos per month. The total cost per unit was US$0.10/kWh. In non-electrified households, consumption of candles, fuel for wick lamps, and other alternative energy sources equated to approximately 1.25kWh/month, for which the average residential consumer paid almost 19 Bolivianos/month. The expenditure per unit was thus US$1.91/kWh. Therefore, the unit cost for lighting in communities without electricity in Potolo was almost 20 times greater than the cost of electricity. The economic benefit for lighting was estimated at US$17.88/month.

The disparity between the amount and cost of klmh for electricity and alternative energy sources was clearly dramatic, and resulted in a substantial economic benefit for the non-electrified consumers of Tomoyo.

As a corollary, Table 4 presents the formula and calculation for the consumer economic benefit for non-lighting uses of energy.

Table 3. Formula and calculation of consumer economic benefit for lighting (Tomoyo project)

Lighting only - Surplus To Consumer*: D = Qa*(Pa-Pe)+((Pa-Pe)/2)*(Qe-Qa)			
Whereas:			
Pe	Price of Electricity	US$/klmh	0.021
Pa	Price of Traditional Energy Sources	US$/klmh	0.38
Qe	Consumption of Electricity for Lighting	klmh/month	92.72
Qa	Consumption of Traditional Energy Sources for Lighting	klmh/month	6.26

Qa klmn/month	(Pa-Pe) US$/klmh	(Pa-Pe)/2 US$/klmh	(Qe-Qa) klmn/month	Economic Benefit - Lighting US$/month
6.26	0.36	0.18	86.46	17.88

*Source: World Bank Report No. 255/02, "Rural Electrification & Development in the Philippines: Measuring the Social & Economic Benefits"

Table 4. Formula and calculation of consumer economic benefit for other uses of energy (Tomoyo project)

Other Uses of Energy - Surplus to the Consumer*: D=Qa*(Pa-Pe)+((Pa-Pe)/2*(Qe-Qa)			
Whereas:			
Pe	Price of Electricity	US$/kWh	0.10
Pa	Price of Traditional Energy Sources for Other Uses	US$/kWh	1.42
Qe	Consumption of Electricity for Other Uses	kWh/month	16.8
Qa	Consumption of Traditional Source of Energy for Other Uses	kWh/month	0.64

Qa kWh/month	(Pa-Pe) US$/kWh	(Pa-Pe)/2 US$/kWh	(Qe-Qa) kWh/month	Economic Benefit for Other Uses US$/month
0.64	1.32	0.66	16.12	11.48

*Source: World Bank Report No. 255/02, "Rural Electrification & Development in the Philippines: Measuring the Social & Economic Benefits"

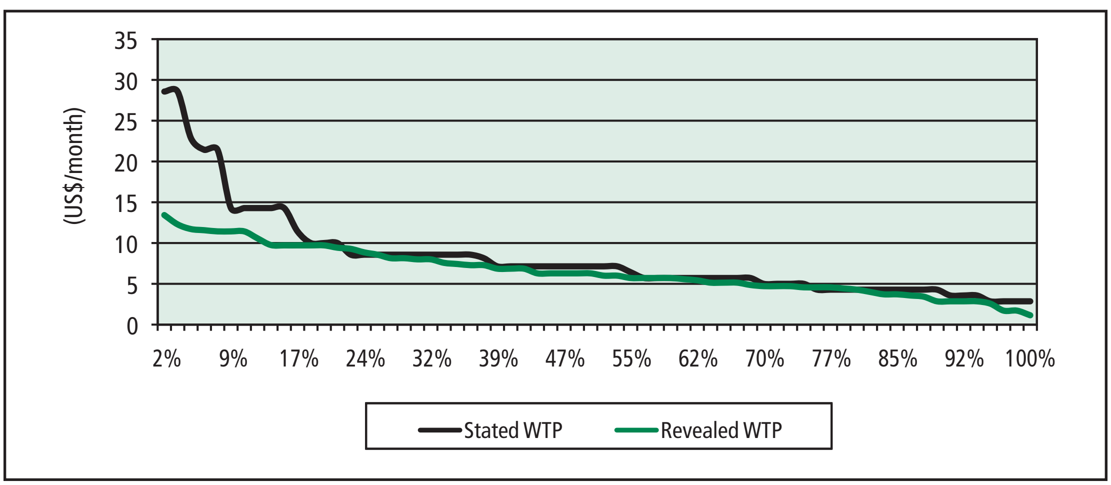
Presenting the Final Results

With all of the analyses of consumer WtP and economic benefit complete, the results should be presented to the reader in a clear and concise manner. The presentation of analytical results should include graphics, charts, and/or figures, with accompanying text that provides interpretation and support. The final results should include the Expressed and Revealed WtP for alternative energy sources and electricity, consumption of electricity, and the economic benefit for the individual consumer as well as for the project. The results obtained from the theory, methodology, and analysis described in this module become not only an end to this process but also important inputs for the technical and financial analysis of the project.

The results of the Expressed and Revealed WtP for electric service can be presented in many different ways. The following charts present some concrete examples.

Figure 6 illustrates the comparison between the Expressed and Revealed WtP for a community surveyed in Haiti. There was no existing electric infrastructure in the community and therefore

Figure 6. Expressed vs. Revealed WtP (Haiti project)



the results indicate only the Revealed WtP for alternative energy sources. The chart indicates that the majority of surveyed individuals spent more than US$5.00 per month for alternative energy sources. Their Expressed WtP reveals that they were willing to pay more for electric service than indicated by their current Revealed WtP.

The results from surveys conducted in the Dominican Republic offer a perspective on a different reality. In this case, the majority of interviewees had access to electricity, but due to frequent and prolonged blackouts, they had to spend additional money on alternative energy sources. Therefore, their Revealed WtP adds together their expenditures for alternative energy sources and for electricity from the national grid.

Figure 7 shows the Revealed and Expressed WtP for the CEF project in the Dominican Republic. Note that the Revealed WtP curve intersects with the US$20/month line at the point representing 20% of the population. This means that 20% of the population spends more than US$ 20/month and the remaining 80% of the population spends less than US$20/month on energy sources.

Obviously, there exists a large gap between the results illustrated for the Dominican Republic and Haiti, not only in their respective levels of consumption, but also in their Expressed WtP. In the Dominican Republic, the interviewees indicated that they were not willing to pay more than what they were presently paying for energy. However, in Haiti respondents said they would be willing to pay more for electric service than their Revealed WtP indicated.

Another way of showing Revealed WtP is in the form of a table or chart. Table 5 demonstrates the Revealed WtP of energy consumers in the Dominican Republic. At one extreme, 7.1% of the population spends US$2.50/month or less

Figure 7. Expressed vs. Revealed WtP, (CEF project)

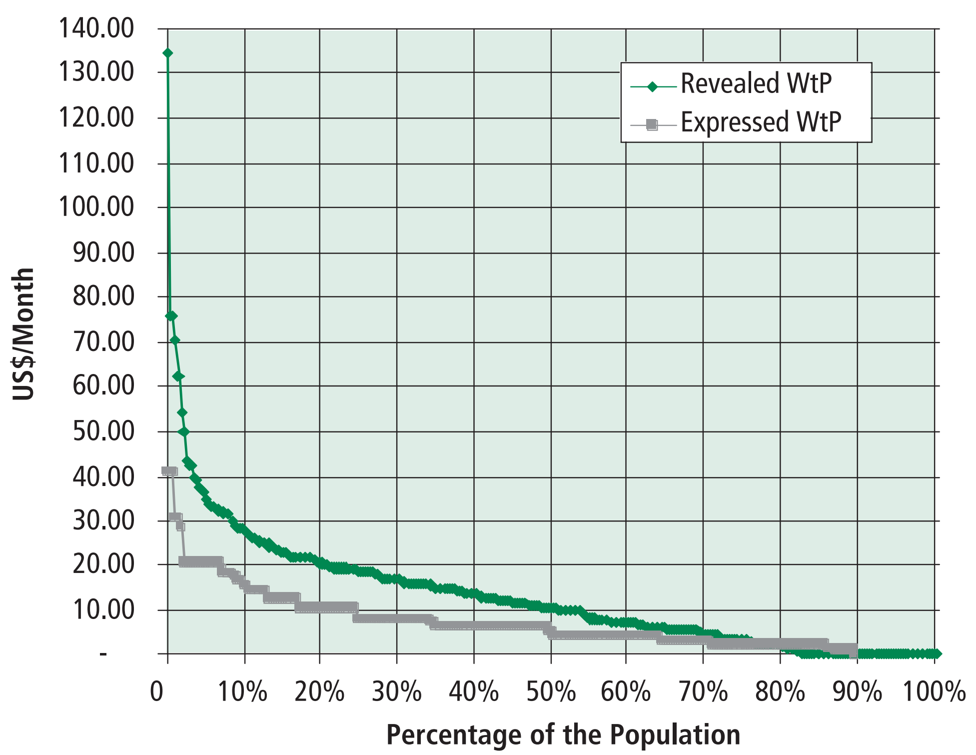


Table 5. Revealed WtP in the electric sector

Revealed WtP (US$/month)	Percentage	Accumulated Percentage
1 < = 2.50	7.10%	7.10%
2 > 2.50 < = 5.00	11.10%	18.20%
3 > 5.00 < = 7.50	14.00%	32.20%
4 > 7.50 < = 10.00	13.00%	45.20%
5 > 10.00 < = 15.00	15.40%	60.60%
6 > 15.00 < = 20.00	10.30%	70.90%
7 > 20.00 < = 50.00	17.70%	88.50%
8 > 50.00 < = 100.00	6.00%	94.50%
9 > 100	5.50%	100.00%
Total	**100.00%**	**100.00%**

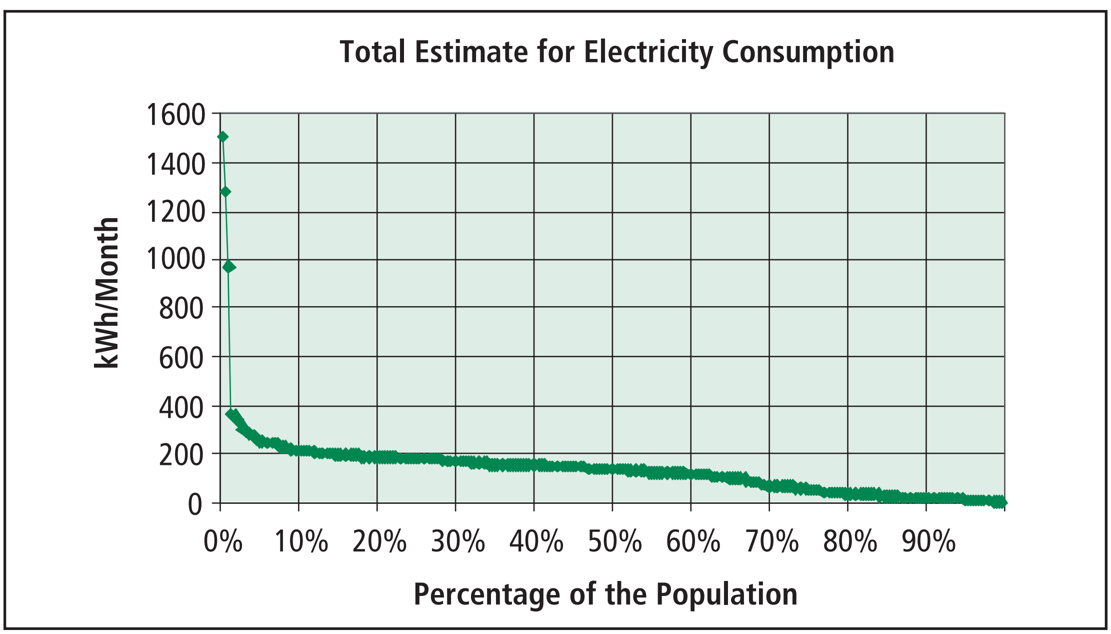
on energy, while 5.5% spend more than US$100/month. The reader can see that in the accumulated percentage column, almost 71% of the residential population spends US$20 or less per month.

Figure 8 illustrates residential and commercial electricity consumption in the CEF project area in the form of a demand curve.

In the figure below, 35% of the population consumes less than 100kWh/month while roughly 15% of the population consumes more than 200kWh/month. Between these two points, there exists a flat section of the curve (extending from approximately 15% up to 65% of the population) equating to 50% of the population consuming between 100 to 200kWh/month.

For such purposes as tariff studies or subsidy considerations, it is important to view the WtP results in terms of unit costs. Table 6 indicates consumer WtP in US$/kWh for residential

Figure 8. Demand curve for electricity



consumers in the Dominican Republic. The exhibit demonstrates that the unit price of electricity is more expensive for the consumers on both extremes of the consumption curve. Those who consume the least (who in turn are the poorest) and those who consume the most (the majority of which have their own portable generator) are the ones who pay the most per kWh. For example, from the residential population, consumers of less than 50kWh/month paid an average of US$0.30/kWh, while those who consumed more than 1,000 kWh/month paid US$0.32/kWh.

The next to last column of Table 6 shows the monthly expenses for energy sources (Revealed WtP) as a percentage of the general monthly expenses included in the fourth column. The last column shows the expenses for electricity as a percentage of monthly expenses. The survey asked certain questions related to monthly expenses, such as expenses for food, housing, health, education, etc. The sum of all these expenses was used as an estimated indicator of family income. This amount appears in the fourth column of Table 6.

Results of economic benefit analysis are normally shown using charts, but they can also be presented as bar graphs that illustrate the difference between energy costs and value of the alternative energy sources and electricity.

Using the WtP Results in Technical and Financial Analysis

The feasibility analysis of an electrification project requires understanding the relationship among the economic, financial, and engineering analyses, as well as the contribution of each analysis in determining the feasibility and design of the project.

The analyst requires multiple parameters from different sources for a complete analysis. Table 7 shows a summary and examples of parameters used in a feasibility analysis of an electrification project and the source of each parameter.

Along with the parameters in the chart, the information intake includes vital demographic information, such as the number of families that live in the target region of the project. The engineering analysis must also have information available concerning the location of the houses and the energy source. Tools such as GPS data, satellite images, and aerial photographs are useful in this process, along with physically counting the number of houses in the community.

Growth rates for consumer demand projections and project load forecasts can be procured from a variety of sources, as illustrated in Table 8.

Table 6. Revealed WtP (Dominican Republic, residential consumers)

Consumption Range (kWh/month)	Percentage of the Residential Population	Average Revealed WtP (US$/kWh)	General Monthly Expenses (US$/month)	Monthly Revealed WtP as % of Monthly Expenses	Electric Bill as % of Monthly Expenses
1 < = 50	6%	0.30	144	6%	2%
2 > 50 < = 100	5%	0.19	175	7%	3%
3 > 100 < = 200	43%	0.15	243	10%	6%
4 > 200 < = 300	18%	0.16	416	9%	5%
5 > 300 < = 700	17%	0.21	731	13%	7%
6 > 700	11%	0.32	1,768	30%	19%
Total	**100.00%**				

Table 7. Summary of analysis parameters

Parameter	Value	Source
Coverage (initial)	70%	WtP Study
Coverage (from 5 up to 20 years)	90%	Past data from the electric company that will operate the project, and experience of the team
Average residential consumption (kWh/month)	130	WtP Study Past data
Average commercial consumption (kWh/month)	250	WtP Study Past data
Write-offs (%)	6%	Past data from the electric company that will operate the project, and experience of the team
Collection Index (%)	90%	Past data from the electric company that will operate the project, and experience of the team
Scope of analysis (years)	20	Set by the analysis team
Interest (%)	8%	Financial conditions in the country
Discount rate (%)	12%	Discount rate used in the country
Cost of purchased energy (US$/kWh)	0.07	Prevalent prices in energy purchasing contracts
Income Tax (%)	25%	Laws in effect
Municipal Tax (%)	3%	Laws in effect

Contribution to the Financial Analysis

The data and analysis on consumer WtP represent essential input for project financial analysis, as they influence the determination for a cost of service tariff, project penetration rate, and the number of consumers that are estimated to be connected by the project, from implementation onward for a defined time period (often 20 years). Combining the average consumption in kWh/month, the number of users, and the consumer WtP allows the project manager to run models of analysis for different scenarios and in this way, determine the final tariff rate.

Contribution to the Engineering Analysis

Project engineering analysis requires knowing the estimated number of consumers to be connected to the system, the estimated amount of electricity that will be consumed, and the geographic location of the consumers. The WtP study and economic benefit calculation can contribute to these three variables depending on how responsibilities are assigned and what data already exists.

With reference to the number of users, the first thing to know is the total number of houses in the region of the project. There are several

Table 8. Summary of growth rates

	Annual Growth Rate (%)	Source
Population	1	National census adjusted to the target region
Number of Residential Users	3	Past data from the electric company
Number of Productive Uses	4	Past data from the electric company
Consumption of Public Lighting	1	concerning growth rate of the population
Residential Consumption	3.6	Past data from the electric company
Productive Use Consumption	5	Past data from the electric company

ways to obtain this information. In some cases, recent census data is available and reliable. In many cases, however, either no census has been conducted recently or the results are not reliable. Data can also be obtained from satellite images or aerial photographs. These images and photos must have a resolution that allows for the counting of each house. If it is not possible to obtain "number of houses" data by other means, then field workers must physically count the houses in the community. This becomes more feasible when the community is small and in a relatively compact region. Since it is important not to duplicate efforts, coordinate such counting with other project teams, such as the engineering team.

After counting the total number of houses in the region, determine the percentage of the population that will connect to the project. The results from the WtP study will help define the percentage of coverage and/or the penetration rate. Using the WtP study and an estimate for consumption in kWh/month, along with the rate scenarios, the analyst can create and evaluate a corresponding model for the analysis.

Average consumption of electricity can usually be determined from the willingness-to-pay data of communities without access to electricity. The amount of electricity that the beneficiaries could acquire, at different rates, derives from the amount of money spent monthly on alternative energy sources.

Geographic location is another important aspect in the design of the electric system. Preferably a team of trained technicians conducts a geographic study. In some cases, the WtP survey team can take a GPS device with them to obtain some preliminary geographic information, such as the locations of existing substations, electrical poles, large transformer banks, etc.

Contribution to Determining Subsidy

Analysts use the economic benefit results to determine the maximum subsidy that should be provided to the project. If the cost of investment per consumer required to execute the project is greater than the economic benefit, then the investment is not justified. To obtain this information, calculate the NPV of the economic benefit for the term of the analysis (often 20 to 30 years).

For the Tomoyo project in the Department of Potosí, Bolivia, the total economic benefit to the consumer was US$29.36/month or approximately US$352 per year. Considering a term of twenty years, the NPV of the economic benefit is approximately US$3,000 per consumer. An investment cost of US$500,000 was assumed based on estimated material and equipment costs to connect 600 consumers. The cost per consumer was US$833. Therefore, the project is justified because the NPV of the economic benefit is greater than the investment cost. This project could be subsidized at 100% of the capital cost of the project and still present a net economic benefit for the country.

For the CEF project in the Dominican Republic, the total economic benefit was US$10 per month. The NPV was approximately US$1,179. The engineering analysis and the financial analysis estimated a total of 16,000 consumers (even though this number could grow up to 17,000 or more in the future). The cost of the CEF project was estimated at approximately US$7 million, which, when divided by 16,000 consumers, results in a cost of US$438 per consumer. This project is also justified because the NPV of the economic benefit is greater than the investment cost. As with the Tomoyo Project, 100% of the capital cost of the CEF project could be subsidized and still present a net economic benefit for the country.

Analysts use the economic benefit results to determine the maximum subsidy that should be provided to the project. If the cost of investment per consumer required to execute the project is greater than the economic benefit, then the investment is not justified.