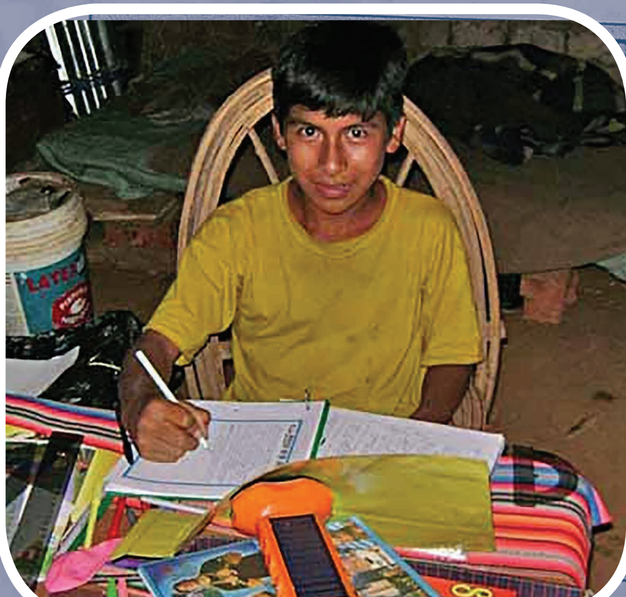


IDB

Measuring the Benefits of Energy Access

A Handbook for Development Practitioners

Douglas F. Barnes
Hussain Samad

Measuring the Benefits of Energy Access

A Handbook for Development Practitioners

Douglas F. Barnes, Hussain Samad.

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Barnes, Douglas F.
Measuring the benefits of energy access: a handbook for development practitioners / Douglas F. Barnes, Hussain Samad.
p. cm. — (IDB Monograph ; 653)
Includes bibliographic references.
1. Rural electrification-Handbooks, manuals, etc. 2. Renewable energy sources-Handbooks, manuals, etc. 3. Clean energy- Handbooks, manuals, etc. 4. Energy development-Handbooks, manuals, etc. I. Samad, Hussain. II. Inter-American Development Bank. Energy Division. III. Title. IV. Series.
IDB-MG-653.

JEL codes: D63, Q48, Q42, Q49, Q18
Key words: Energy, Energy Access, Rural electrification, Development, Sustainable Energy, Energy Policy

http://www.iadb.org

Contents

Acknowledgments ix

Abbreviations and Acronyms xi

Executive Summary xiii

Transition to Modern Energy and Development Pathways xiii
Under-Measured Benefits of Energy Access xix
The Challenges Ahead xxi

PART 1. METHODS 1

Chapter 1. Introduction 3

Study Purpose and Approach 4
Structure of the Handbook 7

Chapter 2. Benefit Pathways of Modern Energy Access 9

Transition to Modern Energy 10
Benefit Pathways of Electricity 12
Benefits of Access to Clean Cooking 13
Conclusion 15

Chapter 3. Measuring Benefits: From Consumer Surplus to Regression Techniques 17

History of Cost-Benefit Methodologies 17
Consumer Surplus as a Measure of Benefits 21
Regression-Based Direct Approach to Measure Benefits 27
Conclusion 34

Chapter 4. Conducting a Socioeconomic Impact Survey 35

Survey and Sample Design 36
Questionnaire Design 42
Existing Types of Energy Used in the Household 45
Other Measures Important for Energy Use 48
Additional Aspects of Conducting the Survey 51

PART 2. BENEFITS ESTIMATION 53

Chapter 5. Electrification Benefits: Consumer Surplus Approach 55

The Switch to Electric Lighting 55
Use of Radio and TV 60
Use of Mobile Phones 64
Use of Computers and Fans 68
Conclusion 69

Chapter 6. Electrification Benefits: Regression-Based Approach 71

Necessary Control Variables 71
Measuring Variables 74
Use of Refrigerator 78
Kerosene Consumption 80
Income, Employment, Expenditure, and Poverty 82
Income-Generating Activities 87
Education 95
Health 99
Conclusion 103

Chapter 7. Assessing the Benefits of Clean Cooking: Regression-Based Approach 105

Benefits of Clean Cooking 106
Quantitative Technique 107
Cooking and Kitchen Characteristics 109
Time-Savings Benefits 112
Measuring Variables for Time Savings 113
Income Benefits: Energy Expense and Time Savings 114
Health Impacts 116
Conclusion 117

Chapter 8. Under-Measured Benefits of Energy Access 119

Environment 119
Reduction in Kerosene Use 121
Women's Time Use and Empowerment 123
Public Lighting 125
Potable Water 127
Conclusion 127

Chapter 9. Conclusion: Energy Access and Measurement Issues 129

Evaluating the Benefits of Electricity 129
Evaluating the Benefits of Clean Cooking 133
Which Approach Is Preferred? 134
Conclusion 137

References 139

PART 3. ANNEXES 147

Annex A. Philippines Household Energy Survey Module 149

Annex B. Peru Household Energy Survey Questionnaire 169

Annex C. Generic Socioeconomic Impact Questionnaire 199

Annex D. Conversion Factors for Kerosene and Electric Lighting 229

Boxes

3-1. What does it mean to measure project benefits? 21
4-1. Steps of the socioeconomic impact survey 36
4-2. Possible research topics for questionnaire 43
4-3. Typical fuels in rural areas of developing countries 45
4-4. Assessing the quality of electricity service 48
4-5 Impacts of electric lighting 49
5-1. Making the switch: Benefits of electric lighting 56
5-2. Calculating consumer surplus for watching TV in Peru 65
6-1 Household-level control variables 72
6-2. Village-level control variables 73
6-3. Energy access variables 74
6-4. Electrification impacts on economic outcomes in Bangladesh 94
6-5. Electrification impacts on educational outcomes in India 101

Figures

ES-1. Benefit pathways for household electrification xv
ES-2. Flow diagram showing direct benefits to households adopting improved cookstoves xviii
2-1. Benefit pathways for household electrification 12
2-2. Flow diagram showing direct benefits to households adopting improved cookstoves 14
3-1. Evolution of project methods for evaluating rural electrification 18
3-2. Estimation of consumer surplus for lighting from household demand curve 23
5-1. Questions on kerosene and electric incandescent lamps 58
5-2. Questions on radio use 61
5-3. Questions on TV use 63
5-4. Questions on mobile phone use 67
6-1. Questions related to mandatory, household-level control variables 75
6-2. Questions to capture household land assets 76
6-3. Village questions: General questions and fuel price 77
6-4. Village questions: Infrastructure and availability of services 77
6-5. Exogenous village shocks 78
6-6. Questions on refrigeration for regression-based approach (all households) 79
6-7. Questions on kerosene consumption 82
6-8. Interrelationship among employment, income, expenditure, and poverty 84
6-9. Simplified questions to collect household income 85
6-10. Simplified questions to collect household food expenditure 86
6-11. Questions to collect recurring household nonfood expenditure 86

6-12. Questions to collect non-recurring household nonfood expenditure 86
6-13. Income from home business 91
6-14. Questions to collect income from separate business 91
6-15. Questions to collect control variables (X) for nonfarm income-generating activities 92
6-16. Questions to collect income from agricultural activities 93
6-17. Questions on control variables for farm income-generating activities 93
6-18. Pathways from electrification to higher income through education 96
6-19. Questions to collect an additional control variable at the household level for outcome equation for grade attainment 99
6-20. Questions on school characteristics as part of school questionnaire 100
6-21. Questions to collect an additional control variable at the individual level for health outcomes 102
6-22. Questions to collect health-facility characteristics 103
7-1. Questions related to stove adoption 109
7-2. Questions to collect information on additional control variables for improved cookstove outcome equations 110
7-3. Simplified household fuel-use questions 111
7-4. Characteristics of biomass stove questions 112
7-5. Questions on time savings in fuel collection and meal preparation 114
8-1. Women's time-use questions 124
8-2. Women's empowerment questions 126

Tables

2-1. Transitions to grid and renewable energy in developing countries 11
3-1. Possible list of choices for computer in contingency value question 26
B5-2.1. Cost and viewing hours for television 65
B6-4.1 Household electrification impacts on economic outcomes in rural Bangladesh 94
B6-5.1 Household electrification impacts on educational outcomes in India 101
9-1. Comparing strengths and weaknesses of methodological approaches 136

Acknowledgments

This report was prepared by the Inter-American Development Bank's Energy Division (ENE). The lead authors were Douglas F. Barnes and Hussain Samad under the general coordination of Roberto G. Aiello, Principal Energy Specialist, ENE. The report benefited from the inputs of Arnaldo Vieira de Carvalho, Javier Castillo and Michelle Hallack, ENE, as well as of the editorial support of Norma Adams and graphic design provided by Michael Alwan.

Abbreviations and Acronyms

B&W	Black-and-White (TV)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPU	Computer Processing Unit
CV	Contingency Valuation
DID	Difference-in-Difference
ESMAP	Energy Sector Management Assistance Program
FE	Fixed Effects
GHG	Greenhouse Gas
IAP	Indoor Air Pollution
ICS	Improved Cookstove
IDB	Inter-American Development Bank
IV	Instrumental Variable
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
M&E	Monitoring and Evaluation
MFI	Microfinance Institution
NGO	Nongovernmental Organization
PM	Particulate Matter
PSM	Propensity Score Matching
PV	Photovoltaic
RDD	Regression Discontinuity Design
SDG	Sustainable Development Goal
SEforAll	Sustainable Energy for All
SHS	Solar Home System
WTP	Willingness to Pay

Units of Measure

kg	kilogram
klm	kilolumen
klmh	kilolumen-hour
km	kilometer
km^2	square kilometer
kWh	kilowatt-hour
mg	milligram
m	meter
m^3	cubic meter
ppm	parts per million
W	watt

Executive Summary

Impact evaluation has gained recognition over the last decade as an essential component of project development. Impact evaluation details how and to what extent policies and project interventions contribute to socioeconomic welfare gains or losses for society. Such evaluations are also important for identifying key lessons for future policies and investments. In the case of modern energy access, the measurement of costs is fairly straightforward. However, measuring the benefits to society is more difficult and might involve implementing national or regional surveys. Past efforts have often underestimated the complex linkages of benefits produced by programs involved in providing electricity and clean cooking energy to rural and other populations without access to modern energy services. Thus, it has often been difficult to balance the costs of program investments in energy access vis-à-vis their benefits.

This study's main objective is to develop a practical method by which to measure the benefits of rural energy, including both electricity and clean cooking. The methods reviewed in this report involve both formal and informal techniques of data collection, including quantitative and qualitative methods of analysis. The research pays attention to such concepts as quality of life, effects on education, and other key components of social development; that is, it tackles those benefits of modern energy access that traditionally have been difficult to measure, as well as the easier-to-measure benefits.

Transition to Modern Energy and Development Pathways

The transition from traditional to more modern forms of energy is clearly under way as households in developing countries begin to adopt electricity

and clean methods of cooking. The terms *traditional* and *modern* refer to both the fuel type and the technologies that use it. Wood, for example, can be burned quite inefficiently using a traditional open fire with high levels of pollutants. However, wood chips can be gasified and burned as a high-quality, modern cooking fuel, with high combustion efficiency and little pollution. In the case of household lighting, kerosene is a traditional form of lighting, offering poor-quality light and low efficiency. Depending on the lighting technology used, electric lamps can give off 100 times more light compared to kerosene lamps or candles (O'Sullivan and Barnes 2007; Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1998). Electric lighting enables household members to read, socialize, and be more productive during the evening, and has also been associated with greater school attendance by children (Khandker, Barnes, and Samad 2013; Khandker et al. 2014).

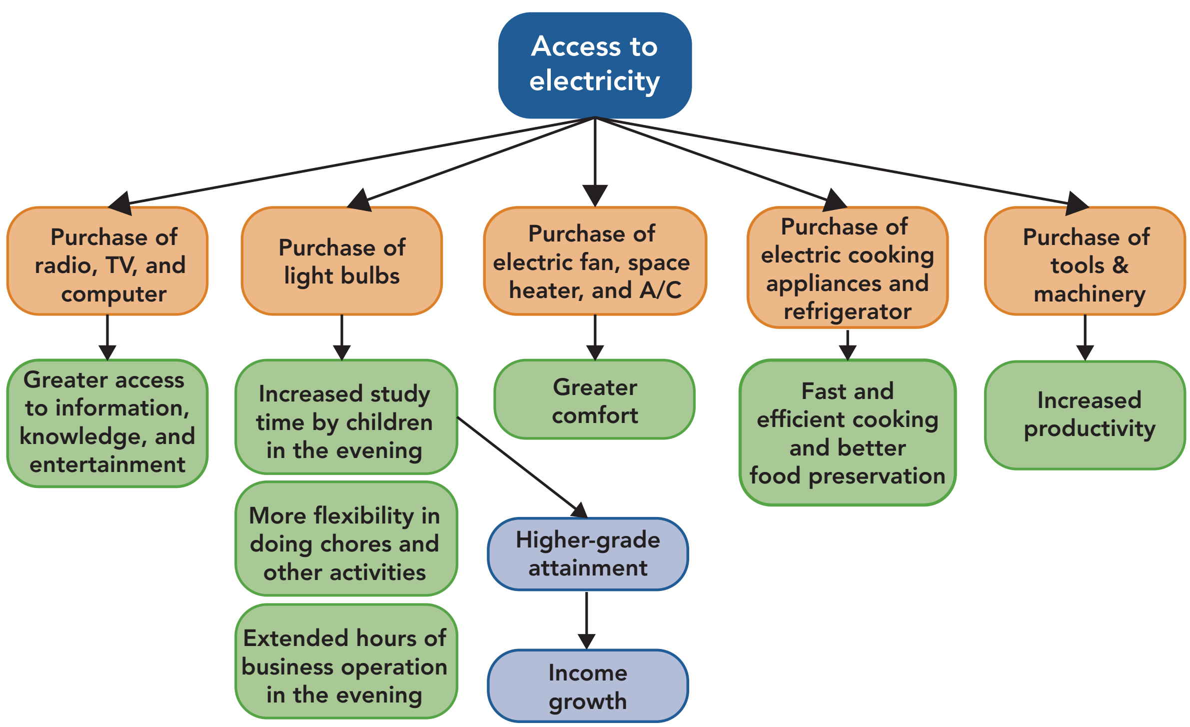
Benefits of Electricity

Even in quite remote areas, grid electricity and many renewable energy sources (e.g., solar PV household systems, micro hydro–powered minigrids, and solar pumps) can provide modern energy services, including quality lighting, communications, motive power, and heating and cooling. Recent developments with biomass-based generating systems are encouraging. Unfortunately, statistics on renewable energy use in rural areas of developing countries are not being collected systematically by any international organization. As a result, it is generally difficult to detail the progress of renewable energy in off-grid areas for all developing countries.

The pathways between the introduction of electricity and development outcomes (e.g., higher incomes, better health, and increased education) are quite complex, which is one reason many studies prefer to use such methods as consumer surplus to measure the benefits of electricity. Consumer-surplus methods do not trace the pathways through which electricity has an impact on development; instead, they measure the value of higher levels of light as measured by people's willingness to pay for lighting service. But to understand the benefits, it is necessary to delve into the ways that electricity affects development outcomes.

The pathways of electricity for development all start with the purchase of appliances. After adopting electricity, households purchase a variety of appliances, starting with electric lights, followed by radios, television sets, computers, electric fans, space heaters, air conditioners, cooking appliances (e.g., microwaves and rice cookers), and refrigerators. These appliances, in turn, lead to immediate and long-term impacts on a host of outcomes. Using electric bulbs, households enjoy a quality of lighting that is much brighter than that possible with kerosene lamps. With higher-quality lighting, household members can be expected to engage in a wider range of activities. For example, children might spend more time in studies and adults might engage in productive activities, such as handicrafts. As children's study hours increase, one can expect they will have higher school attendance and eventually higher grade completion. Higher grade attainment is not only a better outcome in its own right; it might also result in a higher future income. Future income might also increase for some households with home businesses that can be kept open for longer hours in the evening (figure ES-1).

Figure ES-1. Benefit pathways for household electrification



Source: This study.
Note: This figure was first used in a report measuring the socioeconomic benefits of rural electrification in the Philippines (World Bank 2002a), and was further developed in later studies.

Measuring the benefits of energy access on development has evolved over the years to include two basic approaches. The first approach is based on the concept of willingness to pay and consumer surplus, while the second is the regression or direct method of estimating the benefits of energy projects. Consumer surplus, perhaps the most common approach used in project appraisals, is a solid economic technique that is not overly complicated to apply. Unfortunately, because of its simplicity, this method has been misapplied on occasion. The main weakness has been not quantifying energy demand based on consumer surveys. The regression method, also based on consumer surveys, is more demanding. It uses multivariate estimation techniques, which must deal with confounding influences related to development outcomes. Since income and the adoption of modern energy are often intertwined, this direct approach must also deal with issues of causality.

Benefits of Clean Cooking

Open fires and primitive stoves have been used for cooking since the beginning of human history. They have come in various sizes and styles, having been adapted to myriad cultures and food preparation methods. As society has progressed, more sophisticated stove models have been developed. Today's modern kitchens reflect the many types of standardized and specialized cooking devices available, from coffee pots and tea kettles to toasters and gas stoves.

The types of energy that households use have significant consequences for the health of family members, particularly women, as well as the environment. In most of the developing world, people rely on traditional ways of cooking and heating. Typically, biomass fuels (e.g., fuelwood, dung, and crop residues) are burned in traditional stoves that are highly inefficient and harmful to health. Throughout the developing world, the time and effort spent collecting biomass fuels has been increasing because of localized biomass fuel shortages. Women are the primary group affected by this increasing drudgery since, in most developing regions, they play a critical role in biomass management, including responsibility for fuel collection and use.

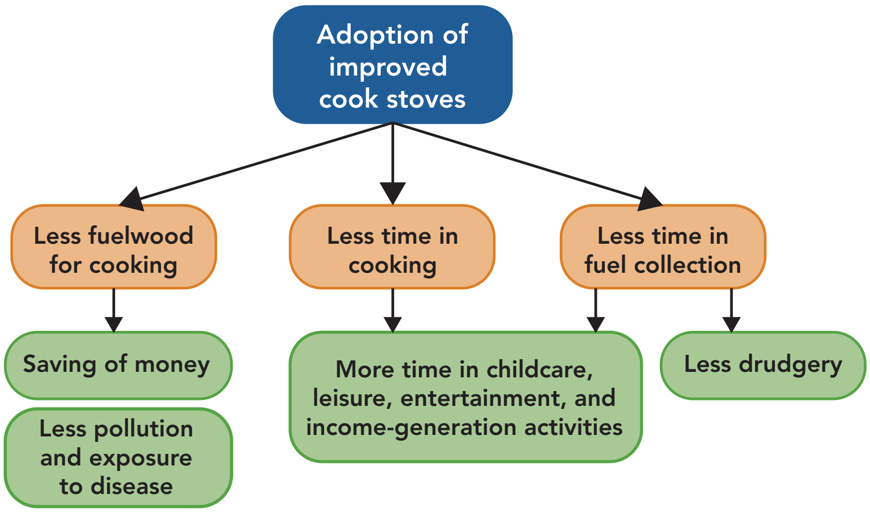
Unfortunately, today many people in developing countries still burn biomass energy on primitive stoves to meet their household cooking needs. These open fires are fairly inefficient at converting energy into heat for cooking.

The annual amount of biomass fuel for meeting basic cooking needs can reach up to 2 tons per family. Collecting such a large amount of fuel can translate into spending an hour per day on this task. Furthermore, open fires and primitive cookstoves emit a significant amount of smoke, which fills the home. This indoor cooking smoke has been associated with a number of diseases, the most serious of which are chronic and acute respiratory illnesses including bronchitis and pneumonia. Moreover, where demand for local biomass energy outstrips the natural regrowth of local resources, environmental problems can result. There is evidence that biomass fuels burned in traditional ways contribute to a build-up of greenhouse gases (GHGs) (Venkataraman et al. 2010). Some studies have alleged that the black carbon emitted from traditional stoves can have adverse environmental impacts (Ramanathan and Carmichael 2008).

Compared to traditional cookstoves, modern stoves (e.g., improved biomass, electric, or LPG) cook food more efficiently, meaning that households can use less cooking fuel (particularly fuelwood and other biomass). Thus, the adoption of modern cooking methods saves fuel, which means freeing up time or money. If the family saves disposable income, this can be spent on the purchase of consumable and durable goods, entertainment, and income-generating activities. Some households might save time using better stoves. Less time is spent collecting fuelwood, and even cooking can be faster compared to using a traditional stove. This time saved can be used for childcare, entertainment, and income-generating activities. Another important benefit of improved cookstoves is the improved health of all household members, especially women. By using less biomass fuel and making complete combustion of the fuel, improved cookstoves emit less smoke and pollutants, thereby reducing the likelihood of health hazards due to indoor air pollution (IAP) (figure ES-2).

The benefits of energy access and clean cooking are not easily measured. Unlike measuring the costs of program interventions, which is fairly straightforward, measuring the benefits requires sorting out the complicated pathways through which both energy access and clean cooking have an impact on development outcomes. Household and community surveys are also required to measure benefits. Once completed, some standard methods that have been developed are used to disentangle and measure program benefits.

Figure ES-2. Flow diagram showing direct benefits to households adopting improved cookstoves



Source: This study.

Many of the benefits of employing clean cooking methods are quite obvious.[1] First and foremost are the savings in cooking fuel and time. Improved cookstoves can be up to 40–50 percent more efficient than their counterpart traditional or open-fire stoves. The substantial fuel savings can mean more disposable income for households. Secondly, cooking with improved cookstoves or commercial fuels (e.g., LPG) is faster than preparing food with traditional stoves. The time savings refers to both cooking time and time spent collecting fuelwood or other local energy sources. Fuel collection, which is often done by women and children, involves walking long distances. The drudgery of carrying loads of fuel back home to cook evening meals may take hours.

The benefits of moving away from traditional cooking patterns are many, entailing various dimensions. Among others, they include health, time savings, and reduced fuel use. The main benefits of clean cooking are as follows:

- *Time saved in cooking and fuel collection*. Women's time savings in cooking and fuel collection can be redirected to more productive and satisfying

[1] Clean methods of cooking include improved biomass cookstoves, high-pressure kerosene stoves, and LPG stoves. In this chapter, the term *improved cookstove* refers to all methods of clean cooking.

activities, while children's time savings in fuel collection can be reallocated to studying.

- *Savings in fuel use*. The substantial savings in fuel from using clean cooking methods can also mean more disposable income.
- *Less smoke and improved health*. Moving away from traditional cooking methods also produces less IAP than traditional stoves, thereby promoting better respiratory health.
- *Climate change*. Cleaner cooking methods also have implications for climate change. With improved cookstoves, the more efficient burning of biomass fuels reduces GHG emissions and may contribute to mitigating global warming. Widespread dissemination of cleaner cooking methods can also reduce deforestation.

Households can increase available income from clean cooking in various ways. Of course, these benefits must be measured against the cost. The cost of clean cooking would involve the purchase of an improved biomass, kerosene, or LPG stove. For kerosene and LPG, the household would also have to spend money on monthly fuel expenditures. Once the savings in the time spent collecting fuel and cooking have been calculated, these savings must be measured against the cost of adopting clean methods of cooking. Clean cooking methods generally result in biomass fuel savings. The adoption of LPG, kerosene, or improved cookstoves means that less biomass fuel will have to be collected or purchased to cook the same amount of food. The savings in firewood can sometimes be quite substantial, depending on the efficiency of the new stove and its use. If wood or other biomass fuels are purchased, this savings can mean a direct increase in disposable income for the household. If the biomass fuel is collected, then it means a decrease in time collecting fuels for use in the traditional stove. The opportunity cost of this time is typically valued at the local cost of manual labor.

Under-Measured Benefits of Energy Access

The benefits of changes in energy access typically occur at the household or community level. These benefits include better education, cleaner cooking, and a higher quality of household lighting, among others. Beyond these, however, there is another class of benefits that is harder to measure. Many people are concerned that, as households switch from renewable biomass to commercial fuels, this increase in energy access may result in higher levels of harmful pollutants emitted into the atmosphere. While partially true, the gain in energy efficiency from moving away from traditional fuels means that households use less biomass or petroleum fuels. Nearly 2 billion people without electricity use polluting kerosene lamps, as well as candles and other inferior types of lighting. Making the switch to electricity means that overall pollution levels may decline despite the higher service levels. The greater efficiency of modern fuels might actually lead to environmental benefits.

The under-measured or difficult-to-measure benefits of modern energy use are as follows:

- *Environmental benefits*. Not surprisingly, most programs to alleviate carbon emissions are targeted toward the larger countries where carbon emissions are already quite high. In fact, most climate change studies totally ignore collected cooking fuels in their scenarios. Although complicated, measuring the climate change benefits of cleaner cooking is possible.
- *Reduction in kerosene use*. A reduction in kerosene consumption for lighting lowers IAP, which is a household-level benefit. Moreover, reducing the accumulated effect of kerosene burning on global warming can have a societal or global benefit. Household savings in kerosene consumption resulting from household electricity adoption can be useful in calculating the reduction in carbon dioxide (CO_2) emissions. While other GHGs are also emitted by burning kerosene, CO_2 is considered the largest contributor to global warming.
- *Women's time use and empowerment*. With electricity in the household, women are enabled to take advantage of labor-saving devices. Since women tend to spend more time than men inside the home, they are more exposed to the benefits of electricity. Measuring the benefits of energy access for women requires that surveys include questions on women's time use and empowerment. Electrification and adoption of clean cooking methods free up women's time from drudgery and household chores. As a result, they can engage more in productive and satisfying activities.

- *Public lighting*. Public lighting, in the form of street lighting, provides a sense of security to all residents in the community covered by the public lighting. While existing studies on the effects of street lighting focus mainly on crime reduction, street lighting also improves safety for pedestrians and drivers. Valuation of the benefits of public lighting is difficult as there is no established way to assign value to crime reduction in a community.
- *Potable water*. Electricity is also necessary for rural water supplies. In most cases, rural water supplies rely on electric pumps to lift water from safe sources into small storage units. This water is then piped to households in the community or community taps. The benefits of electricity for rural water supply are difficult to measure because they are an input into other programs.

Finally, many studies have also shown that electricity, combined with clean cooking, leads to a reduction in cooking time. The time savings could be substantial, particularly for women. As previously mentioned, this additional time might be used for such other activities as starting a new business or caring for children. The value of these activities would be hard to measure, so once again the time savings could be valued at the local cost of manual labor.

The Challenges Ahead

Measuring the benefits of energy access is not an easy task. Many of the earlier electrification studies involved simple comparisons of households with and without electricity. The drawback of those approaches was not taking confounding factors into consideration. Such earlier methods have since evolved to include both the consumer surplus and regression methods for valuing the benefits of energy access. Along with the evolution of methods for valuing benefits, these methods, by necessity, have become more technical and the surveys more complex and complete. The result has been a better understanding of how energy access impacts development outcomes, which, in turn, has meant a better understanding of the significant monetary benefits of energy access.

Many development agencies today are requiring better monitoring and evaluation (M&E). Past investments often plunged ahead into unsuitable areas. The resulting impacts of energy access were limited to a small number of wealthy households. The techniques described in this handbook provide the tools for analyzing the benefits of energy access in both monetary and more general terms. These tools can be helpful in directing programs toward areas where improvements in energy access can have the greatest impact on development. In addition, energy access programs can be coordinated with other development projects and programs to ensure that the right complementary conditions are in place to make the most of modern energy.

PART 1

Methods

Chapter 1
Introduction

Impact evaluation has gained recognition over the last decade as an essential component of project development. The concept of measuring energy access is of significant growing interest among governments and development agencies owing, in part, to the launch of the United Nations Sustainable Development Goals (SDGs) in 2015. These new international policies more explicitly recognize the catalytic role of energy access in economic, social, and human development. Universal access to modern energy services means that all households should have access to electricity and clean cooking fuels. Doubling the share of renewable energy in the global energy mix means generating more power from wind, geothermal, solar photovoltaic (PV) cells, biogas, and other sources of clean energy.

Impact evaluation details how and to what extent these new policies and project interventions contribute to socioeconomic welfare gains or losses for society. Such evaluations are important for identifying key lessons for future policies and investments. In the case of modern energy access, the measurement of costs is fairly straightforward. However, measuring the benefits to society is more difficult and might involve implementing complex national or regional surveys. Past efforts have often underestimated the complex benefits produced by programs involved in providing electricity and clean cooking energy to rural and other populations without access to modern energy services. Thus, it has often been difficult to balance the costs of program investments in energy access vis-à-vis their benefits.

Measuring the socioeconomic benefits of energy access has been difficult for various reasons. The attribution of causality is an issue for measuring the impact of energy access that must be addressed. Also, some measurable qualitative benefits are difficult to translate into monetary terms. For example, the benefits of the perception of improved safety from household lighting, while fairly intuitive, are difficult to measure in quantitative form. That energy access sometimes has a greater impact when combined with other enabling infrastructure (e.g., schools, water and sanitation services, or availability of loans for purchasing household appliances and productive-use equipment) further complicates the issue. Sorting out these issues is difficult but possible using the appropriate methodologies and techniques.

In most parts of the world, electricity is considered a modern source of energy that is essential to development. Areas without access to modern energy are generally far less developed. The availability of electricity has at least the potential to improve quality of life and increase economic activity. Rural areas benefit from electricity access in many ways, including improved business and farm productivity, enhanced convenience of household tasks, and a far more efficient form of household lighting. However, electricity by itself does not lead to any development because its effectiveness requires intermediary inputs, including lamps for lighting, availability of books for reading, and schools for educating students. In the past, the benefits of rural electrification programs have, in some cases, been disappointing owing to a lack of complementary programs or local availability of appliances for purchase. Clean cooking also can save time for women, improve health, and reduce air pollution. However, measuring these benefits is not an easy task.

Study Purpose and Approach

This study's main objective is to develop a practical method by which to measure the benefits of rural energy, including both electricity and clean cooking. The methods reviewed in this report involve both formal and informal techniques of data collection, including quantitative and qualitative methods of analysis. The research attends to such concepts as quality of life, effects on education, and other key components of social development; that is, it tackles those benefits of modern energy access that traditionally have been difficult to measure, as well as the easier-to-measure benefits.

Need for Better Methods to Assess Development Outcomes

Estimates of rural electrification's benefits are sometimes based on consumer cost.[2] However, cost estimates alone are not particularly relevant for estimating benefits because they fail to reflect the full spectrum of development benefits that energy access makes possible. Rather than focus narrowly on financial issues provided by cost data, this study's approach considers the full breadth of services provided by electricity. For example, while consumers do benefit from the less expensive lighting provided by an electric light bulb, as compared to a kerosene lamp, they also benefit in terms of adult and child literacy. Similarly, availability of electricity may lead farmers to increase irrigation, resulting in higher farm income with less seasonal variation. Understanding the relatively complex linkages between rural energy, enabling infrastructure (e.g., roads and schools), and development outcomes is essential to understanding the benefits for a project, region, or country.

In recent years, international donor agencies and other development organizations have increasingly emphasized development outcomes, such as poverty reduction, income generation, and improved quality of life—an emphasis more closely aligned with the benefit-estimation techniques advocated in this study. The approach first identifies the development outcomes of rural electrification, including any synergies with other infrastructure, and then finds ways to assess the value of those outcomes in monetary terms. Though not an easy exercise, it is necessary in order to evaluate how electricity fits within the context of other development priorities. For example, having electricity in a home, which enables children to study in the evening, may play as great a role in raising educational attainment levels as does having a school in a community.

In fact, studies have shown that some types of social infrastructure are complementary rather than competing. In Peru, for example, it was found that the combination of electrification and schools has a greater effect on educational achievement than does each factor considered independently (World Bank 1999). Such complex interdependencies are not reflected in isolated cost or financial data. Thus, this study aims to design and implement a method for

[2] This section is based on a report prepared for the Philippines on estimating the impact of rural electrification (World Bank 2002a).

improving valuation of benefits derived from rural electrification and clean cooking. Specifically, it estimates the monetary value of benefits derived from electricity services in terms of better opportunities for education, health, entertainment, comfort and convenience, and productivity, as well as the cost benefits of providing a less expensive means of lighting. Clean cooking can improve health, reduce time spent on cooking and fuel collection, and decrease air pollution.

Relevance of the Approach

While there is consensus that rural electrification and cooking energy are critical to a country's development, policy formulations require that the benefits be expressed in monetary terms. Monetary measures of benefits serve a variety of purposes. First, benefits and costs provide objective criteria for choosing between electrification projects or electrification and other sector projects, such as roads or public health. Second, knowledge of the types and scale of benefits that access to electricity provides rural areas can help determine the most appropriate project size (e.g., a massive grid project or a smaller-scale solar PV program). Third, the scale of societal benefits can help determine appropriate pricing policies and whether subsidies are needed. Finally, quantitative benefit numbers are essential for drawing any objective conclusions about the economic efficiency of proposed projects; that is, whether social objectives could be achieved with fewer resources and how the benefits of a rural electrification project might compare with those of other projects.

To serve these policy needs, one should bear in mind that it is not only important to measure benefits quantitatively; it is also important to include as many potential benefits in the analysis as possible. While many World Bank and Inter-American Development Bank (IDB) studies have acknowledged that electrification contributes broadly to societal well-being, many of the benefits have been defined quite narrowly. Since the year 2000, the benefit pathways of energy access have been understood in theory, but tracing them in systematic ways has only been done in a haphazard manner.

This study brings together many of the disparate measurement techniques that have been broadly applied to evaluating the impact of increasing access to modern energy so that researchers can more easily track the progress. The aim of the measurement tools presented is to broaden the methods and techniques that can be applied to measuring the socioeconomic impact in developing countries. By using a broader set of tools, it is possible to estimate some of the previously underestimated energy-access benefits

Any measurement of the benefits of energy access requires an understanding of the pathways between adopting modern energy and the value ultimately derived from using it through appliances and machinery. In this study, the pathways of interest include the impact of substituting electricity for kerosene and such economic outcomes as income, expenditure, poverty, and employment. Education is also an important development outcome, and methods are discussed on how to measure the impact of study time, school enrollment, and grade attainment. For improved cooking methods, health outcomes may be important and include incidence of short-term illnesses related to indoor air pollution (IAP), days lost due to illnesses, and cost of treatment. Other measures of impact may include time-related issues (e.g., time spent collecting fuelwood and cooking). In addition, the expense of wood and other modern energy sources may have an impact on evaluating development outcomes.

Structure of the Handbook

This handbook is divided into two parts: methods (Part 1) and benefits estimation (Part 2). Part 1 is organized into three chapters. Chapter 2 uses a systematic framework to trace the benefits of electricity and clean cooking from adoption made possible by programs that promote modern energy in developing countries to possible development outcomes. Chapter 3 offers a technical introduction to the two most common estimation approaches used to measure the benefits of energy access: (i) consumer surplus and (ii) regression-based direct techniques. Chapter 4 follows with a concise summary of how to conduct energy surveys essential for measuring the impacts of modern energy for development. Part 2 is organized into five chapters. Chapter 5 details how the consumer surplus method can be used to estimate electrification benefits for a range of specific outcomes. It also covers specific survey questions needed for benefits measurement. Chapter 6 provides a framework for evaluating the benefits of energy access using regression-based, direct methods and questionnaires. Chapter 7 turns to measuring the benefits of clean cooking for those adopting modern fuels or stoves, using regional-based approaches. Chapter 8 considers the under-measured monetary benefits of energy access, including environmental benefits and women's empowerment. Finally, chapter 9 discusses how and to what extent the monetary benefits of energy access can be combined to arrive at an overall assessment of energy access benefits.

Chapter 2
Benefit Pathways of Modern Energy Access

To understand the development outcomes of modern energy, it is necessary to examine some of the pathways through which modern energy has an impact. Energy by itself does not cause any kind of development. The free-flowing rivers and streams of the world are teaming with energy, but to have an impact, that energy must be harnessed and turned into something useful. By necessity, it must be channeled through some type of machinery or appliance. For example, electricity must flow through a lamp to create household lighting; in turn, this lighting can be used in many ways, ranging from reading and studying to creating handicrafts. Reading and studying, in turn, can lead to such outcomes as improved education, which often lead to a lifetime of higher income streams.

Once a household adopts electricity, a wide variety of appliances can be purchased. This usually begins with electric lamps, followed by radios, television sets, space coolers, heaters, cooking devices, and small machines. These appliances then produce higher-quality lighting, access to knowledge and information, greater comfort, better food preservation, productive motive power, and more efficient cooking (World Bank 2008). These changes in the household environment can then lead to extended study time, longer hours of home-business operation, greater exposure to business knowledge and information, better health, and more productive activities. Given the multiple channels through which electrification can lead to development outcomes—including greater income, better health, and higher levels of education—the accumulated benefits can be quite high. Before turning to the pathways through which modern energy has an impact on development, the next section examines the impact of various types of modern energy important for development.

Transition to Modern Energy

The transition from traditional to more modern forms of energy is clearly under way as households in developing countries begin to adopt electricity and clean methods of cooking. The terms *traditional* and *modern* refer to both the fuel type and the technologies that use it. In a traditional open fire, wood burns quite inefficiently and emits high levels of pollutants. However, wood chips can be gasified and burned as a high-quality, modern cooking fuel, with high combustion efficiency and little pollution. In the case of household lighting, kerosene is a traditional form of lighting, offering poor-quality light and low efficiency. Depending on the lighting technology used, electric lamps can give off 100 times more light compared to kerosene wick lamps or candles (O'Sullivan and Barnes 2007; Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1998). Electric lighting enables household members to read, socialize, and be more productive during the evening, and has also been associated with greater school attendance by children (Khandker, Barnes, and Samad 2013; Khandker et al. 2014).

Even in quite remote areas, grid electricity and many renewable energy sources (e.g., solar PV household systems, micro hydro–powered mini-grids, and solar pumps) can provide modern energy services, including quality lighting, communications, motive power, and heating and cooling (table 2-1).

Recent developments with biomass-based generating systems are encouraging. Unfortunately, statistics on renewable energy use in rural areas of developing countries are not being collected systematically by any international organization. As a result, it is generally difficult to detail the progress of renewable energy in off-grid areas for all developing countries.

The reality is that the scope of traditional energy services in areas without electricity or better stoves is quite limited. Kerosene does produce light, but traditional wick lamps or candles provide much less light than that available from electric lamps. With 10–15 percent efficiencies, traditional stoves are extremely poor at transforming wood into useful energy for cooking. Many modern services (e.g., television watching and the use of computers) are simply not possible with traditional forms of energy. In rural or underdeveloped areas, the traditional forms of energy used provide only low levels of energy services, which, in turn, limit income for adults and education for children. The high levels of smoke from traditional stoves lowers health for everyone.

Table 2-1. Transitions to grid and renewable energy in developing countries

Rural energy service	Existing off-grid rural energy sources	Examples of modern energy sources
Lighting and other small electric needs (homes, schools, street lighting, telecom, hand tools, and vaccine storage)	Candles, kerosene, batteries, central battery recharging by carting batteries to grid	• Hydropower (pico-scale, micro-scale, and small-scale) • Biogas from household-scale digester • Small-scale biomass gasifier with gas engine • Village-scale mini-grids and solar/wind hybrid systems • Solar home systems (SHSs) • Traditional grid electricity systems
Communications (television sets, radios, and cell phones)	Dry-cell batteries and central battery recharging by carting batteries to grid	• Hydropower (pico-, micro-, and small-scale) • Biogas from household-scale digester • Small-scale biomass gasifier with gas engine • Village-scale mini-grids and solar/wind hybrid systems • SHSs • Traditional grid electricity systems
Cooking (household, commercial stoves, and ovens)	Burning wood, dung, or straw in open fire at about 15 percent efficiency	• Improved cooking stoves (fuelwood, crop wastes) with efficiencies above 25 percent • Biogas from household-scale digester • Solar cookers • LPG stoves • Electric stoves and appliances
Heating and cooling (crop drying, other agricultural processing, and hot water)	Mostly open fire from wood, dung, and straw	• Improved heating stoves • Biogas from small- and medium-scale digesters • Solar crop dryers • Solar water heaters • Ice-making for food preservation • Fans from small-grid renewable system
Process motive power (small industry)	Diesel engines and generators	• Small electricity grid systems from micro hydro, gasifiers, direct combustion, and large-scale biodigesters
Water pumping (agriculture and drinking water)	Diesel pumps and generators	• Mechanical wind pumps • Solar PV pumps • Small electricity grid systems from micro hydro, gasifiers, direct combustion, and large-scale biodigesters • Grid electricity systems

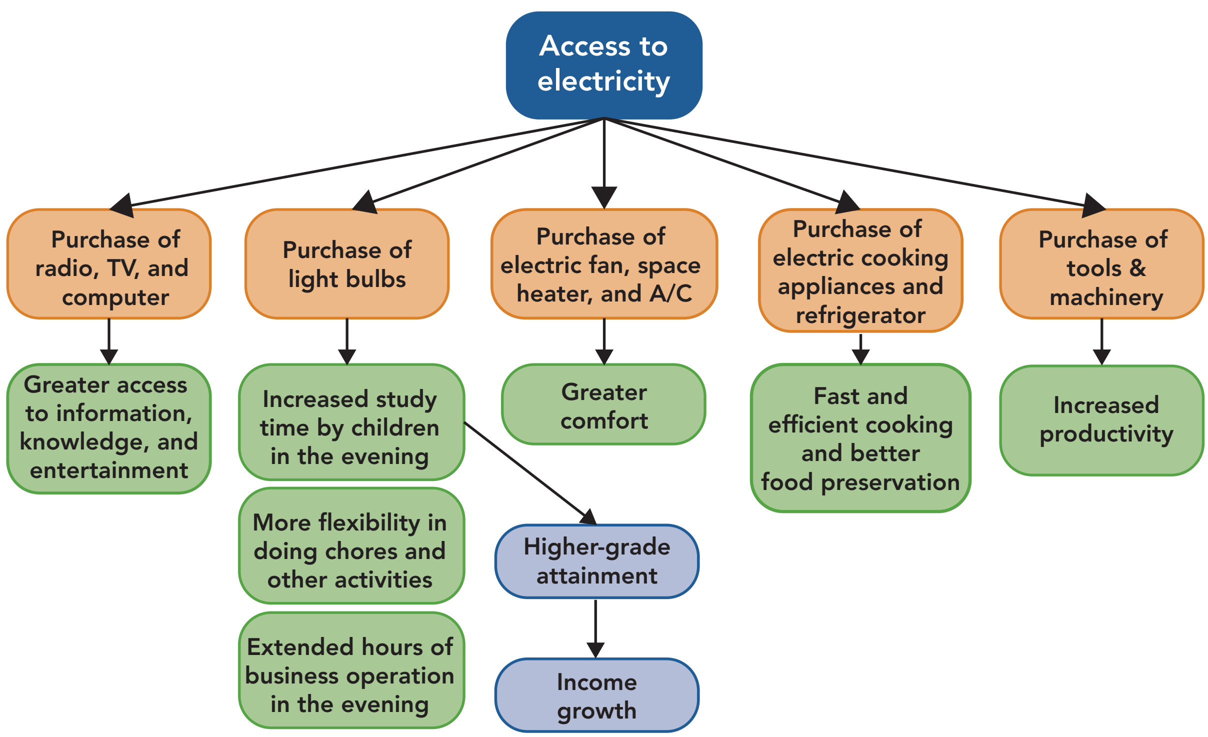
Source: Barnes 2014.

Benefit Pathways of Electricity

The pathways between the introduction of electricity and development outcomes (e.g., higher income, better heath, and increased education) are quite complex, which is one reason many studies prefer to use such methods as consumer surplus to measure the benefits of electricity. Consumer-surplus methods do not trace the pathways through which electricity has an impact on development; instead, they measure the value of higher levels of light as measured by people's willingness to pay for lighting service. But to understand the benefits, it is necessary to delve into the ways that electricity affects development outcomes.

The pathways of electricity for development all start with the purchase of appliances. After adopting electricity, households purchase a variety of appliances, starting with electric lights, followed by radios, television sets, computers, electric fans, space heaters, air conditioners, cooking appliances (e.g., microwaves and rice cookers), and refrigerators. These appliances, in turn, lead to immediate and long-term impacts on a host of outcomes (figure 2-1).

Figure 2-1. Benefit pathways for household electrification



Source: This study.
Note: This figure was first used in a report measuring the socioeconomic benefits of rural electrification in the Philippines (World Bank 2002a), and was further developed in later studies.

Using electric bulbs, households enjoy a quality of lighting that is much brighter than that possible with kerosene lamps. With better-quality lighting, household members can be expected to engage in a wider range of activities. For example, because of higher-quality lighting, children might spend more time in studies and adults might engage in productive activities, such as handicrafts. As children's study hours increase, one can expect they will have greater school attendance and eventually higher grade completion. Higher grade attainment is not only a better outcome in its own right; it might also result in a higher future income. Future income might also increase for some households with home businesses that can be kept open for longer hours in the evening.

The increased use of radio, TV, and computers means increased access to information, knowledge, and entertainment. Increased knowledge can lead to better income-earning opportunities and improved hygiene, implying better health for those in households with electricity. Increased knowledge can also lead to greater empowerment of women. Electric fans, air conditioners, and space heaters make life more comfortable. Electric cooking appliances and refrigerators provide faster cooking and better food preservation, resulting in better health. Finally, with electricity, households can use more electric tools and machinery for productive activities, making them more efficient and raising their income. The list is by no means comprehensive.

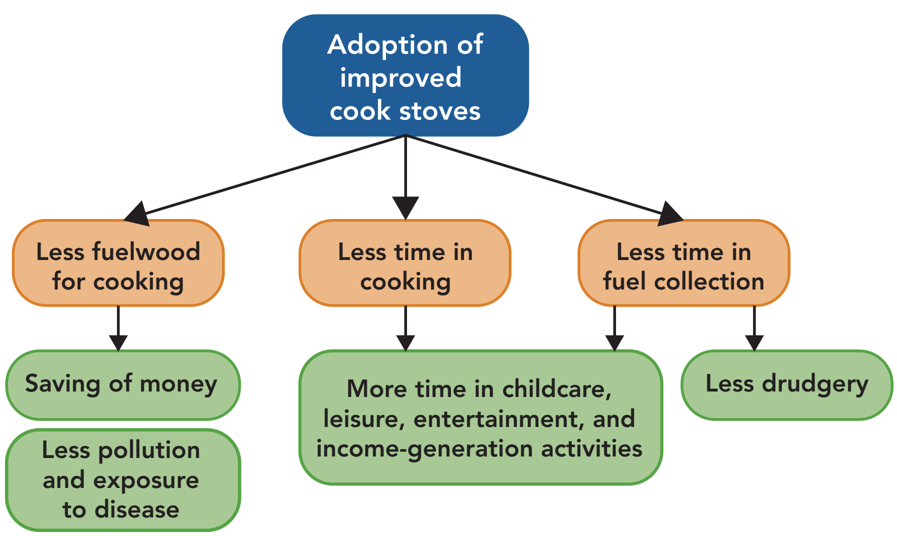
In this study, two approaches are used to measure the benefits of electricity. One is the consumer surplus approach to quantifying the benefits of accessing electricity services (e.g., lighting and TV watching). The second is a regression-based (econometric) technique to more directly quantify the benefits between electricity and various outcomes (e.g., education, health and income). Both approaches, discussed in chapter 3, measure different aspects of the same pathways between electricity and development outcomes.

Benefits of Access to Clean Cooking

The types of energy that households use have significant consequences for the health of family members, particularly women, as well as the environment. In most of the developing world, people rely on traditional ways of cooking and heating. Typically, biomass fuels (e.g., fuelwood, dung, and crop residues) are burned in traditional stoves that are highly inefficient and harmful to health. Throughout the developing world, the time and effort spent collecting biomass fuels has been increasing because of localized biomass fuel shortages. Women are the primary group affected by this increasing drudgery since, in most developing regions, they play a critical role in biomass management, including responsibility for fuel collection and use.

Modern cookstoves (e.g., improved biomass, electric, or LPG) are more efficient for cooking food than traditional cookstoves; as a result, households can cook using less fuel (biomass in general and fuelwood in particular). Thus, the adoption of modern cooking methods saves fuel, which means freeing up time or money. If the family saves disposable income, this can be spent on the purchase of consumable and durable goods, entertainment, and income-generating activities. Some households might save time using better stoves. Less time is spent collecting fuelwood, and even cooking can be faster compared to using a traditional stove. This time saved can be used for childcare, entertainment, and income-generating activities. Another important benefit of improved cookstoves is the improved health of all household members, especially women. By using less biomass fuel and improving fuel combustion, improved cookstoves emit less smoke and pollutants, thereby reducing the likelihood of health hazards due to indoor air pollution (IAP) (figure 2-2).

Figure 2-2. Flow diagram showing direct benefits to households adopting improved cookstoves



Source: This study.

The value of the long hours spent by women on arduous, unhealthy, and unpleasant tasks often goes unrecognized in developing countries. One problem with programs involving clean cooking is that they often fail to count these unrecognized benefits. The impact of women's adoption of modern energy services may result in improving women's health and quality of life, reducing their time spent collecting fuels, reducing cash expenses for fuelwood, and decreasing pressure on local woodlands. Thus, the design of clean cooking programs should quantify these uncounted benefits. In this way, the costs of clean cooking interventions can be compared to the benefits of the program.

Conclusion

The benefits of energy access and clean cooking are not easily measured. Unlike measuring the costs of program interventions, which is fairly straightforward, measuring the benefits requires sorting out the complicated pathways through which both electricity access and clean cooking affect development outcomes. Household and community surveys are also required to measure benefits. Once completed, some standard methods that have been developed are used to disentangle and measure program benefits. The next chapter turns to the methods and techniques commonly used to evaluate household energy programs.

Chapter 3

Measuring Benefits: From Consumer Surplus to Regression Techniques

Measuring the benefits of energy access on development has evolved over the years to include two basic approaches. The first approach is based on the concept of willingness to pay and consumer surplus, while the second is the regression or direct method of estimating the benefits of energy projects. Consumer surplus, perhaps the most common approach used in project appraisals, is a solid economic technique that is not overly complicated to apply. Unfortunately, because of its simplicity, this method has been misapplied on occasion. The main weakness has been not quantifying energy demand based on consumer surveys. The second approach is the regression method. While also based on consumer surveys, it is more demanding. It uses multivariate estimation techniques, which must deal with confounding influences related to development outcomes. Since income and the adoption of modern energy are often intertwined, this direct approach must also deal with causality issues.

This chapter begins by examining the history of evaluating the impact of energy on development, highlighting the techniques used at various stages. This is followed by a more detailed look at the consumer surplus and direct methods of measuring the impact of energy project interventions.

History of Cost-Benefit Methodologies

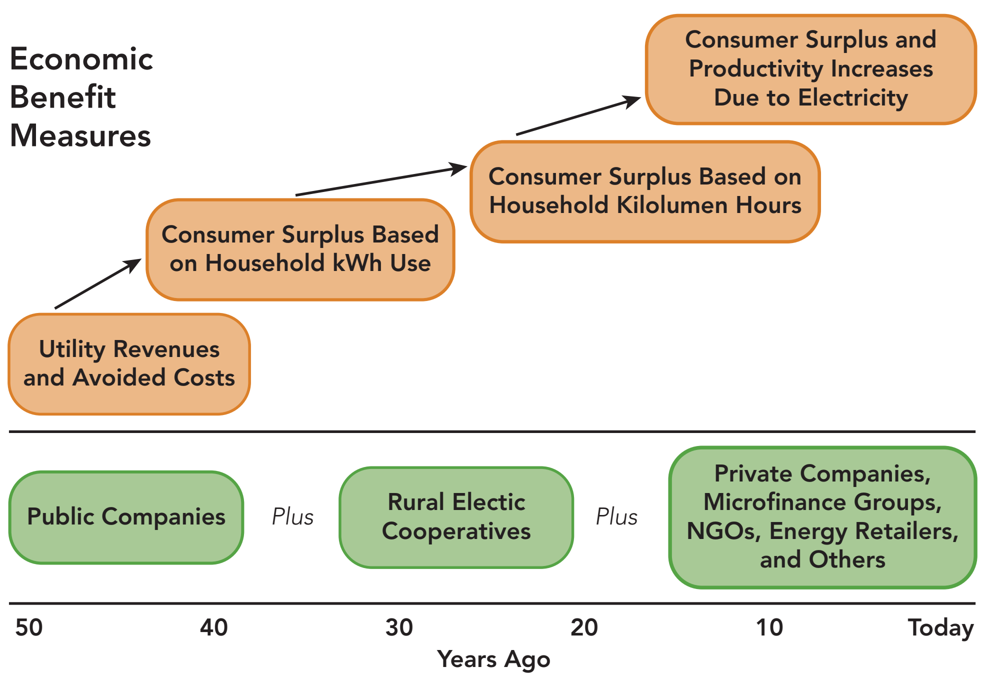
The methods for evaluating rural electrification, along with the methods of supplying electricity to rural areas, have evolved over the last 50 years.[3] From

[3] This section is based on Barnes 2014 (chapter 9).

the 1950s through the 1970s, rural electrification was the exclusive domain of large public electricity companies. During the late 1980s and 1990s, however, these public providers began to face competition from providers of renewable energy and decentralized alternatives. At this time, donors were becoming distrustful of large, politically controlled public companies, which often misdirected electricity to constituents at below the cost of service. As a result, the utilities in some countries became financially unstable and thus underinvested in operation and maintenance. This, in turn, meant that consumers eventually experienced low levels of electricity service, including many brownouts and blackouts.

The 1990s witnessed a call for new ways of delivering electricity to both rural and urban people in developing countries, shifting emphasis from the exclusive dominance of large public companies toward the private sector, renewable energy, and decentralized distribution. These new service providers ranged from large private grid-electricity companies to community organizations providing electricity through small grids (figure 3-1). Also, a variety of

Figure 3-1. Evolution of project methods for evaluating rural electrification



Source: Barnes 2014.

organizations, including retailers, began selling small home-energy devices, ranging from household systems to single lights. Thus, the means of selling electricity evolved from a heavy emphasis on central planning to more decentralized approaches, but the majority of new connections continued to be supplied through grid electricity systems.

During the 1990s, the willingness-to-pay methodology evolved to include consumer surplus. A relatively simple yet often misunderstood concept, consumer surplus is the difference between what consumers are willing to pay for electricity and what they actually pay (see chapter 4 for a detailed explanation). For example, an electricity company may charge a price of 10 cents per kilowatt-hour, while a consumer who values that electricity at a much higher rate reaps a consumer surplus. During the 1980s, this idea was first applied to the demand for kilowatt-hours (Anderson 1975; Pearce and Webb 1985). This was an improvement over the use of revenues as benefits because it took into consideration consumer valuation of the benefits of electricity based on their demand. The drawback was that consumers were not actually demanding kilowatt-hours, but the activities made possible by electricity through the use of such appliances as electric lamps and machines.

The next step was to apply the method of consumer surplus to value the actual end uses of electricity. When households first adopt electricity, they use it for lighting, replacing most of their kerosene lamps. Because electric lighting is of a higher quality and much cheaper than the light produced by a kerosene lamp, households can consume more light at a lower price. The result is that consumers gain the value of additional lighting by adopting electricity. A reason consumers often give for wanting more light is so their children can study at night, which they perceive as a long-term benefit for the family. Women can cook meals more efficiently due to having light in the evening. These are the actual benefit measures, while consumer surplus for household lighting is a shortcut for indirectly measuring such benefits through measuring demand for household lighting.

Whenever possible, it is better to measure the benefits of rural electrification more directly using multivariate analysis since the demand curves for other services are not easily revealed, owing to the small number of demand points (e.g., electricity, battery, or kerosene appliances). In addition, the benefits from non-marketed goods and services are better measured using a variety of indirect techniques borrowed mainly from environmental cost-benefit literature.

This direct or multivariate approach assumes that electricity is a key input to generating goods and services that directly benefit households, including education, health, entertainment and communication, comfort and protection, convenience, and productivity (Tanguy 2012). This measurement requires several steps. First, it is necessary to determine a measure for each of the final outputs. For most of these, the measure is relatively straightforward. For example, education can be measured using years of schooling, entertainment by hours of watching television or listening to the radio, health by morbidity or mortality rates, convenience by time saved, and productivity by output or production. Determining a measure for comfort or protection, however, may be more difficult.

The next step is to assess the differences in final outputs between households with and without electricity, which requires a carefully designed survey of representative households. The effect of electrification or change in outputs must be quantified. Because final outputs in most cases are affected by other factors beyond electrification (e.g., income), some type of multivariate modeling is usually needed.

Finally, quantifying the value of the impact requires estimating the households' willingness to pay for increments in final outputs resulting from electrification. The precise method used depends on the final output under consideration (box 3-1). For example, a household's willingness to pay for increased education could be reasonably estimated from the increase in household income resulting from this education. The income value of an additional year of education is fairly well known in most countries.

The use of consumer surplus, along with any anticipated productivity increases, can generally be used in most project appraisals, but it is important to avoid double-counting benefits. For example, consumer surplus for household lighting estimated as a benefit may also include the benefit of household production made possible by improved lighting during the evening. The direct method using multivariate analysis is a more accurate, but less practical, way to evaluate the benefits of rural electrification. Some examples from recent research are presented in the next sections.

Box 3-1. What does it mean to measure project benefits?

Benefit or well-being is essentially a psychological concept that depends on physical factors facing the household, such as level of wealth, amount of consumption, or state of the environment. While the costs or prices of such factors may affect their physical levels, they should not directly affect the well-being of a rational household. If one household paid US$30,000 for an automobile for which another paid $50,000, then, under assumptions of rationality, the second household would not be considered better or worse off (all else being equal). Thus, the heavy dependence of consumer surplus on prices is considered a deficiency of the method as a measure of benefits—what economists refer to as "money illusion."

Fortunately, consumer surplus is a good approximation of two accepted benefit measures that do not share this defect (but are harder to estimate): (i) the equivalent variation measure and (ii) the compensating variation measure. These measures monetize the physical factors by assigning prices: original or base prices for the former and post-policy prices for the latter. In fact, consumer surplus lies between the two.

Source: Peskin 2006.

Consumer Surplus as a Measure of Benefits

The consumer surplus approach has long been used to measure project benefits. As mentioned above, it is defined as the difference between the amount consumers are willing to pay and the amount they actually pay for a product or service. Willingness to pay accounts for all the benefits that will be enjoyed from the product or service in question. For example, the benefits of lighting service may include longer study hours, better indoor air quality, ability to socialize in the evening, and extended working hours. In short, consumer surplus covers the benefits captured by consumers above what they are willing to pay. The subsections below discuss two techniques for measuring consumer surplus: (i) use of a demand curve and (ii) contingent valuation of goods and services.

Measuring Consumer Surplus Using Demand Curve

The demand-curve approach to measuring consumer surplus requires a consumer survey that measures consumer demand for an energy service based on specific technologies. This type of analysis generally involves observing differing consumption patterns when consumers switch from a technology that is priced high to a lower-cost one. In either a before-and-after or with-and-without situation, the demand curve can be constructed from a consumer survey. By observing the price differences as measured in the survey, the potential savings can be calculated. For example, once a household has access to electricity, it may switch from using high-priced lighting (e.g., kerosene lamps) to lower-cost lighting (e.g., one or more electric lamps).

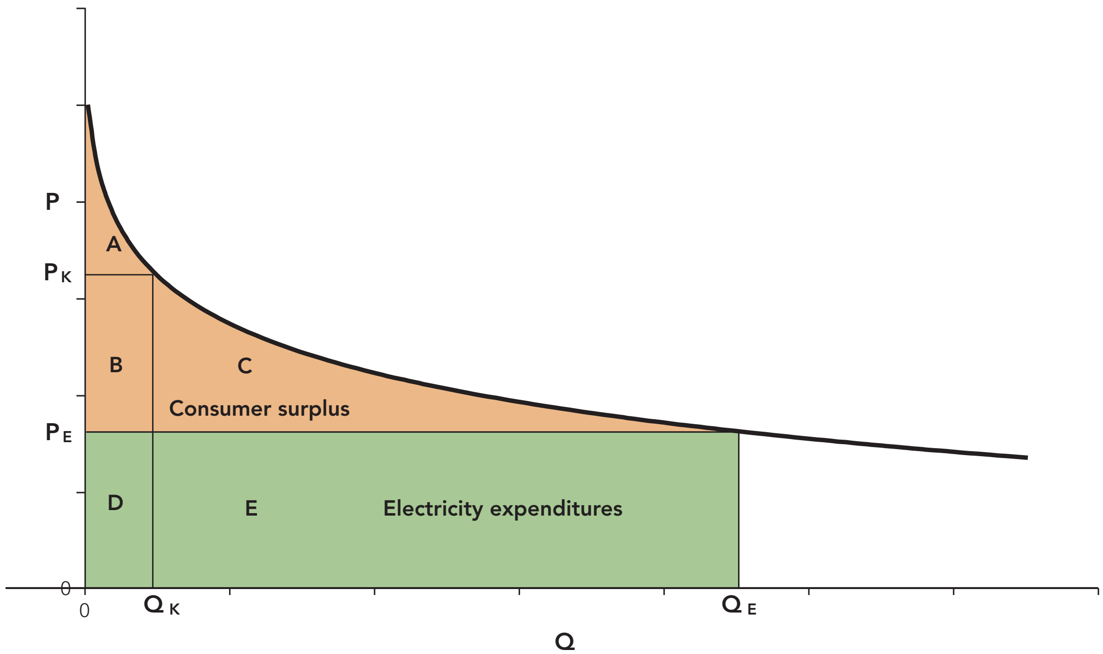
Anderson (1975) first introduced this approach for evaluating the impact of rural electrification on development, using consumption and price per kilowatt-hour to define consumer surplus. This method was further elaborated by a comprehensive study of rural electrification in the Philippines (World Bank 2002a). Because of the large benefits attributed to rural electrification, the method was further reviewed by the World Bank in 2008. That study, which confirmed the validity of the consumer surplus method for evaluating the benefits of rural electrification, recommended a slightly different approach to defining the demand curve (World Bank 2008).

With the adoption of electricity and electric lamps, households no longer have to use kerosene for lighting.[4] Because kerosene used in traditional lamps is an inefficient lighting method, the price of illumination is quite high. Once a household adopts electric lighting, it pays a much lower price and the result is a high level of consumer surplus.[5] To measure the value of consumer surplus gained from switching to electric lights, it is necessary to have a demand curve for lighting, which defines the amount the household is willing to pay for various levels of consumption. The demand curve allows for a measure of household benefit for each level of lighting consumption measured in kilolumen-hours. In figure 3-2, P_K and Q_K represent the respective price and quantity of kerosene kilolumen-hours consumed when the household uses kerosene, while P_E and Q_E are the price and quantity of electricity kilolumen-hours consumed after the household switches from kerosene to electricity. The gain in consumer surplus from switching from kerosene-based lighting to electricity-based lighting is based on the following equation:

[4] For the purpose of defining the benefits of rural electrification, this subsection focuses on the case of lighting as the basis for using consumer surplus and willingness to pay; however, the consumer surplus method can be applied to a variety of other energy services (e.g., communication, entertainment, refrigeration, and space conditioning).

[5] The calculation of consumer surplus demonstrated here is based on the method outlined in World Bank (2008).

Figure 3-2. Estimation of consumer surplus for lighting from household demand curve



Source: World Bank 2008.

$$CS_E - CS_K = \text{area } (B + C) = (P_K - P_E)\, Q_K + \text{area } C, \qquad (3.1)$$

where the amount a household pays for kerosene, AP_K, equals area $(B + D)$ equals $P_K Q_K$; the amount a household pays for electricity, AP_E, equals area $(D + E)$ equals $P_E Q_E$; the amount a household is willing to pay for kerosene, WTP_K, equals the area under the demand curve between 0 and Q_K equals area $(A + B + D)$; and the amount a household is willing to pay for electricity, WTP_E, equals the area under the demand curve between 0 and Q_E equals area $(A + B + D + E + C)$.

The consumer surplus for electricity consumption, CS_E, equals $WTP_E - AP_E$ equals area $(A + B + C)$. This is the benefit of switching from kerosene to electric lighting. Because the households no longer use kerosene, the cost of the previously used kerosene (B) is part of this estimate of consumer surplus involved in adopting electricity for lighting. The value of the area of A is usually quite small and is generally considered a theoretical part of consumer surplus based on the shape of the demand curve.

The use of a properly-designed survey is necessary to measure the price of kerosene per kilolumen-hour (P_K) and the amount of kilolumen-hours from kerosene (Q_K), along with the price and kilolumen-hours from using electricity (P_E and Q_E). The first term in consumer surplus gain [$(P_K - P_E)\ Q_K$] is fairly easy to calculate. However, the shape of the demand curve will determine area *C*. For example, if the demand curve is a straight line, area *C* is given by the formula $0.5(P_K - P_E)\ (Q_E - Q_K)$. However, this formula may overestimate the gain in consumer surplus if the demand curve is convex to the origin, as shown in figure 3-2.

In this exercise, we assume a constant elasticity demand curve (log linear) as suggested by World Bank (2008). However, it should be emphasized that, *if additional points along the demand curve are available, then they may be used to more accurately estimate its shape.* This would be the case if car batteries or PV systems are commonly used in the household survey regions. The formula for the gain in consumer surplus from switching from kerosene lighting to electric lighting is expressed as follows:

$$CS = (P_K - P_E) * Q_K + \frac{K}{\eta+1}(Q_E^{\eta+1} - Q_K^{\eta+1}) - (Q_E - Q_K)\, P_E, \qquad (3.2)$$

where

$$\eta = \frac{ln(P_K) - ln(P_E)}{ln(Q_K) - ln(Q_E)}$$

and *k* is constant in the demand function, given by $P = kQ^{\eta}$.[6]

To estimate the consumer surplus for lighting, it is necessary to have specific lighting questions in the survey measurement instrument. This would include the household cost of total kerosene or electricity for lighting. Also, it is well known that higher-income households without electricity use more kerosene for lighting than poorer households. In some cases, it may be wise to separate out households and estimate consumer surplus for lighting by income class.

The consumer surplus method can be used for more end-use services beyond lighting. Once households adopt electricity they generally switch from battery

[6] For the purpose of demonstration, the demand curve is assumed a log-linear function. It can also be a linear or straight-line function.

to plug-in radios. Similar to the lighting example, use of a battery-operated radio costs more per listening hour than a radio plugged into a grid-based electricity outlet. The same type of situation applies to television sets since battery-operated TVs are more expensive to operate than plug-in sets.

Measuring Consumer Surplus Using Contingency Valuation

The consumer surplus approach discussed above can only be applied when a consumer adopts a new technology that lowers the cost of an energy service. One problem with electricity is that consumers sometimes adopt appliances that offer an entirely new service. Since the estimation of consumer surplus is based on demand surveys, households without electricity, in many cases, simply do not use some appliances because the required power to run them is too high. For example, air conditioning is not possible for households without electricity from grid or mini-grid systems. Computers are rarely used before a household has electricity from a grid-based system. Although laptop computers are powered by batteries, they generally require daily recharging. According to most surveys of households without electricity, the time spent using computers is negligible.

In such cases, consumer surplus can be measured using a regression-based approach called contingency valuation (CV). The CV approach is particularly useful for estimating market demand for services that might be far off in the future or brand new on the market. The idea is to ask consumers to place a monetary value on a preference for some level of a new service (Hoevenagel 1994). Like the demand-curve approach, the CV approach requires the use of a survey to assess consumer preferences.

CV surveys can ask consumers questions about products or services with arbitrary (i.e., random allocated) high and low prices. The survey respondents are asked whether they would purchase those items or appliances. Preferably, this is completed separately for a random sample of consumers within the same survey to avoid a situation of asking the same household questions with varying prices, thus biasing them toward choosing a lower price. Various techniques for conducting CV surveys can be found in a wide body of literature (Cameron and James 1986; Cummings, Brookshire, and Schulze 1986; Mitchel and Carson 1989). In this study, we discuss one method that can be applied to measure certain benefits of electricity services. The purchase behavior of a household can be expressed, using the following equation:

$$D_{ij} = \alpha + \beta X_{ij} + \gamma V_j + \lambda B_{ij} + \varepsilon_{ij}, \quad (3.3)$$

where D_{ij} represents the household's decision to purchase a product or service at a price corresponding to the choice offered; B_{ij} is the price offered; X_{ij} and V_j are household- and village-level exogenous variables; ε_{ij} is the error term, and α, β, γ, and λ are parameters to be determined.

To measure the variable B_{ij}, a list of computer specifications and prices can be prepared for the survey (table 3-1). The specifications might include a certain type of CPU processor, monitor size, or other computer configurations. For each one, three choices are provided, with the middle one corresponding roughly to the average existing price and the other two to a certain higher and lower percent (25 percent is used here).[7] For each household, a choice is randomly selected and asked as a survey question. For example, a household without a computer would be asked whether it would purchase a specific computer configuration at a certain price. The choices offered are randomly selected and uniformly distributed within the survey population.

Once respondents make their choice (whether or not to buy the selected choice), it is then possible to estimate equation (3.3). This is done using a probit

Table 3-1. Possible list of choices for computer in contingency value question

Option	Model number	Price (US$)
1	1	375
2	1	500
3	1	625
4	2	600
5	2	800
6	2	1,000
7	3	750
8	3	1,000
9	3	1,250

Source: This study.

[7] The three combinations shown for the same specification are for demonstration only; more combinations can be produced.

or logit model. This makes it possible to calculate the willingness to pay (WTP) from the choice of computers based on WTP at various price levels.[8]

The mean WTP can be calculated as follows.

$$WTP = -(\alpha + \beta^{*} \overline{X}_{ij} + \gamma^{*} \overline{V}_{j})/\lambda, \quad (3.4)$$

where $\overline{X}_{ij}$ and $\overline{V}_{j}$ are the sample means of X_{ij} and V_{j}.

By subtracting the actual price paid for the product or service from the *WTP*, we obtain the consumer surplus from adopting the product or service, expressed as follows:

$$CS = WTP - \overline{P}_{ij}, \quad (3.5)$$

where $\overline{P}_{ij}$ is the average price of the product or service.

The CV-based, consumer-surplus approach has been used for computers, electric fans, and refrigerators. Practically speaking, some type of grid-based service is necessary for running these energy appliances, all of which require more power than is available through purchased batteries. This means that very few households without electricity—from the grid, mini-grid, or PV system—can adopt these appliances. The use of the CV approach allows for estimating the survey respondents' WTP for these products.

Regression-Based Direct Approach to Measure Benefits

While consumer surplus is a common technique for assessing hard-to-measure benefits of modern energy services, the method is really considered a short-cut for more direct measurement techniques. When possible, rigorous impact evaluation techniques based on multivariate models should be used to assess the benefits associated with energy access and modern energy services. The regression-based direct approach generally addresses whether the development of modern energy services is a cause or an effect of development outcomes.

[8] The underlying theory for estimating WTP is beyond the scope of this discussion; however, a substantial body of literature is available on the subject (see, for example, Choynowski 2002; Gunatilake et al. 2006)

That is, the use of proper statistical techniques can be used to deal with the causality issues that so often plague assessments of the impact of modern energy services for development.

Impact Evaluation: Basic Concepts

The measurement of the impact of modern energy services for any change in development outcome must consider whether the intervention is the cause of the effect. Thus, it is necessary to assess the counterfactual situation, defined as an outcome that would only occur as a consequence of some type of intervention. Take, for example, two identical households without electricity. For whatever reason, one household is provided with electricity service. Over time, both households change because of other circumstances. But the one with electricity has a different set of changes that can be attributed directly to having access to electricity.

The most complicated challenge of any impact evaluation is to deal with the counterfactual aspects of development. Generally, the counterfactual is estimated using a credible control group for comparison. The goal is to identify a participant group and a nonparticipant group that are identical in all aspects except for the difference in their participation status in a project or program. The differences in outcomes between the two groups can then be attributed to participation alone. Basically, identification strategies attempt to identify the control groups in a way that satisfies at least three assumptions (Gertler et al. 2011):

- First, the participants and nonparticipants are identical before the intervention takes place.
- Second, they are expected to behave the same way after receiving the intervention (even though only one group, the participants, receives the intervention).
- Third, during the intervention period, the participants and nonparticipants are not exposed differentially to other factors that can influence the outcome of interest.

Thus, at the heart of any impact evaluation exercise is the challenge of finding a valid control group that can be a good estimate of the counterfactual. Finding a valid control group is not straightforward and is dictated, in large part, by the nature of the intervention. Two types of biases can creep into finding valid comparison groups: (i) program placement bias and (ii) self-selection bias.

Program Placement Bias

Program placement bias arises from nonrandom placement of intervention programs. For example, some projects purposefully select areas that are economically advanced because they have a better chance of success. In other cases, a project may intentionally choose a poor area to compensate for economic inequality. A control group selected from areas that differ significantly from either of these types of intervention areas will not provide a good estimate of the counterfactual since area characteristics (both observed and unobserved) may influence the outcome of interest apart from the intervention itself, resulting in a bias of the estimated impact. For example, a rural electrification project may purposefully select advanced areas because of the likelihood that households will be able to afford electricity. If this is the case, then the control group should not be a random sample; rather, it should contain areas similar to those targeted for rural electrification. Well-off villages with electricity must be matched with similar villages without electricity to properly measure the impact of rural electrification.

Self-Selection Bias

Self-selection bias arises from program participation that is not random. In many cases, project participants self-select themselves to join a program. This may happen when participants that are economically better off can afford to pay for a modern service offered by the project. It can also occur when participants that perhaps are better educated can foresee the program benefits better than the nonparticipants. Because of higher income or better education, such self-selected samples may already have higher levels of education or income compared to those that do not take advantage of project offerings. In this case, any comparison between participants and nonparticipants would be misleading and could lead to an upwardly biased estimate of project impact.

The various types of biases can be controlled for in the proper design of impact evaluation surveys. Project interventions can use two main ways to minimize the impact of sample selection bias: (i) randomized experiments and (ii) nonrandomized interventions.

Experimental Designs

In a randomized experiment, participant and control groups are defined during implementation of the intervention or project in a way that eliminates the possibility of sample selection bias. This can be accomplished by randomly implementing the project for a subset of the eligible population. Such random assignment of the intervention to a treatment group ensures, by theory, that there are no program placement or self-selection biases.

To illustrate, a rural electrification project in a community without electricity might randomly choose those in the community to receive electricity from all households in that community. This would eliminate the bias that wealthier households are more likely to adopt electricity. In this way, the sample size is large enough to assume that the treatment and control groups are similar in terms of both observed and unobserved characteristics. Interventions for improved cookstoves could be implemented in the same way. Formally, the impact in such a scenario is expressed by the following equation:

$$I = Y_2^T - Y_2^C, \tag{3.6}$$

where Y represents measures of the average outcome of the treatment or comparison group, subscript 2 refers to the post-intervention period, and superscripts T and C refer to the treatment and comparison groups, respectively.

In practice, experimental assessments are difficult to achieve for programs involving modern energy services. The reason is that, once a community has electricity, it is difficult to tell better-off households that they cannot participate in the project. Also, connection charges are often not affordable for some populations in the community. Thus, for most infrastructure projects, experimental designs are an ideal, albeit somewhat impractical, way to measure the benefits.

Non-Experimental Designs

Most impact evaluation surveys for evaluating the impact of modern energy services are conducted through randomized surveys of specific populations. The difference from the experimental design is that the intervention is not randomly assigned and is taken as part of the sample design of a normal survey. In such cases, selecting a valid counterfactual is more complicated, requiring the use of statistical analysis. Depending on the type of nonrandomized interventions, one of various non-experimental designs is chosen to construct the counterfactual; these include propensity score matching (PSM), regression discontinuity design (RDD), instrumental variable (IV), difference-in-difference (DID), and matching samples.

In PSM, program participants are matched with nonparticipants using observed household and community characteristics that affect adoption of the intervention (e.g., having an electricity connection). This technique usually requires a large sample size because households are sorted based on various characteristics such that similar households with and without the intervention (e.g., electricity) can be compared. For this method, the probability of adoption is estimated for both treatment and comparison households. This probability or propensity score is estimated as a function of individual characteristics, typically using a logit or probit model. The propensity score is used to create groups of treatment households and nontreatment comparison households. The program impact is estimated by the difference between the observed mean outcomes of the matched participants and comparison groups. Thus, the principle is to compare like households that differ only by the project intervention (e.g., electricity).

The RDD method is applicable in cases with explicit policies for an intervention. For example, a subsidy for an electricity connection cost might be given to those households whose income is below a certain level. In such a situation, the program impact can be estimated for the population at the vicinity of the cut-off point using equation (3.6). This means the treatment households who barely qualified for the intervention are compared to the control households who barely disqualified. The underlying assumption for this estimation technique is that treatment and control groups are quite similar in the vicinity of the cut-off point. For all practical purposes, the intervention is considered randomized for those groups that barely make or miss a household threshold characteristic.

The IV method involves finding suitable instruments that affect the adoption of the intervention but not the outcomes of interest. In reality, however, finding suitable instruments is not easy. This might be the case in which a random survey of households for a community is conducted for the general population. The electricity might have a cut-off point in terms of distance from the electricity lines for allowing consumers to apply for an electricity connection. In this case, the cut-off distance can be used as an IV to control for sample selection bias.

The difference-in-difference (DID) approach, which gives the program impact by the difference in the change in the mean outcome over the intervention period for the treatment and comparison groups, can be implemented if panel data is available. The DID approach assumes that, without the intervention, the final outcomes for the treatment group would have changed by the same amount as the comparison group. Formally, the impact of the DID approach is expressed as follows:

$$I = (Y_2^T - Y_1^T) - (Y_2^C - Y_1^C), \qquad (3.7)$$

where subscripts *1* and *2* refer to the baseline (pre-intervention) and follow-up (post-intervention) period, respectively.

The assumption that the treatment and comparison groups have the same pre-intervention outcomes ($Y_1^T = Y_1^C$), reduces equation (3.7) to equation (3.6). In reality, the participant and comparison groups may vary not only in terms of pre-intervention outcomes, but also in terms of other observed characteristics, which can affect the outcomes of interest. These characteristics may also change between the baseline and follow-up surveys. In such cases, a DID approach will not only capture the program impacts but also the effects of all such external factors, giving a biased estimate of the program impacts.

To control for such biases of the DID approach, a regression-based estimation method is more appropriate. A fixed-effects (FE) estimate with controls for all observed characteristics can be used. The outcome equation used for an FE estimate can be written as follows:

$$Y_{ijt} = \alpha X_{ijt} + \beta V_{jt} + \delta P_{ijt} + \eta_{ij} + \mu_j + \varepsilon_{ijt}, \qquad (3.8)$$

where Y_{ijt} represents the outcome in period t for household i in community j, conditional on program participation; P_{ijt} is the program intervention status of household i in village j (with a value of 1 meaning that the household gets the intervention, and 0 otherwise); X_{ijt} is a vector of household characteristics (e.g., age and education of household head); V_{jt} is a vector of community characteristics (e.g., population or area); η_{ij} is an unobserved determinant of the outcome that is time-invariant within a household; μ_j is an unobserved determinant of the outcome that is time-invariant within a village; ε_{ijt} is the mean-zero error term; and α, β, and δ are the parameters to be estimated. The parameter δ captures the program impact.

The advantage of using an FE model is that it controls not only for the observed factors that can influence the outcomes but also for the unobserved ones (η_{ij} and μ_j) as long as they do not vary over time.

Matched Pairs Sample Design

One underutilized approach to eliminate sample selection bias, which is similar to the PSM technique, is the matched pairs sample design. Unlike PSM, however, which uses large random samples to match households on similar characteristics (e.g., age, sex, and education), the matched pairs sample design matches households in a more direct way. It divides the sample population into strata based on characteristics of interest (e.g., income and education). Then, sample households are randomly selected from each group in a way that simulates matching. By selecting an equal number of treatment and control households from each sample strata, most of the sample selection bias is eliminated. The drawback is that this is a survey specifically designed to measure the impact of a project intervention and does not display characteristics of the overall population.

Approach Selected for This Study

Given that the various techniques used to control for sample bias can become quite complicated, this study opted for using a regression-based estimate of all outcomes. Taking this approach, a simplified version of equation (3.8) (excluding the unobserved variables and subscripts) can be written as follows:

$$Y = \alpha X + \beta V + \delta P + \varepsilon, \tag{3.9}$$

where Y is the outcome variable, P is the program-intervention status of the household, X is a vector of household characteristics (e.g., age and education of household head), V is a vector of community characteristics (e.g., population or area), and δ captures the program impact.

Outcomes can be in monetary terms, such as income, or other forms, such as years of education. Impacts on monetary outcomes can be readily interpreted as monetary gains. The impacts on some of the non-monetary outcomes can be converted into monetary measures based on certain assumptions and empirical evidence. For example, years of education can be given a monetary value based on local studies of improvements in lifetime earnings. Some non-monetary outcomes, such as women's empowerment, cannot be translated into monetary measures. Finally, while household-level outcomes are of primary interest, light is also shed on community or global benefits, such as environmental impacts (e.g., reduction in GHG emissions).

Conclusion

The basic methods for evaluating the impact of energy access for development present many challenges. The consumer surplus method, while easier to implement, must be based on a household energy demand survey, which is often overlooked. Without understanding the demand curve for energy, this method can produce misleading conclusions. Also, consumer surplus is the value that consumers place on energy services based on their willingness to pay for them. It should be emphasized that they do not receive a monetary value from the service. Rather, they receive the value of the service, based on their patterns of purchasing energy services (e.g., for lighting, air conditioning, and entertainment).

The more direct or multivariate methods for estimating the benefits of energy services are even more difficult to implement because they must deal with the issue of causality. The use of modern energy services is often highly correlated with household income and education. Any direct analysis of the pathways between adoption of modern energy services and development outcomes must consider that those who can afford modern energy may be those households with high income. Thus, the complexities of the direct method tend to discourage its use in actual projects.

Development projects are undergoing more scrutiny, and consumer surveys are more frequently being incorporated into project designs. Even before-and-after project surveys are becoming more common. However, monitoring and evaluation (M&E) is frequently treated as a requirement instead of vital information for the success of projects. This situation is changing, but there is still a long way to go before M&E is treated as integral to success rather than a project requirement.

Chapter 4

Conducting a Socioeconomic Impact Survey

Statistical approaches to developing a monitoring and evaluation (M&E) methodology for energy access projects involve the use of surveys based on random samples of households or individuals. The approach typically taken for evaluating projects is to survey households with and without electricity or clean cooking in order to establish a baseline for people living in the project area. The survey (or a portion of it) can be conducted at periodic intervals during execution of the project and can be tailored to specific analysis needs.[9] The cross-sectional approach allows for examining the long-term benefits of rural electrification and clean cooking, using periodic samples to track the progress of projects over time. Both approaches are valid and have their respective strengths and weaknesses. In this chapter, our description is confined to the cross-sectional approach, which can be wholly or partially replicated in later years to yield times-series data on the project's impact.[10]

It should be cautioned that one weakness in the evaluation designs of many rural electrification projects is that the time interval is too short to measure the longer-term benefits, given that projects generally last for about five years. For example, the long-term education of children takes between 10 and 12 years. An evaluation approach that measures only the impact of a project after a few

[9] There are no shortcuts to impact evaluation, and consumer surveys are necessary for all types of analyses; for this reason, this chapter examines the key components of conducting such a survey, while subsequent chapters provide the necessary techniques for extracting information from them.
[10] This chapter is based mainly on World Bank (2003): chapter 4, 32–35.

years would miss the impact of electricity on long-term education. Though longer-term studies are desirable, a lack of resources and interest at the end of projects often hampers the measurement of longer-term project benefits.

Survey and Sample Design

This section identifies the required steps to develop and conduct a cross-sectional survey that can be used to generate quantitative measures of the socioeconomic impacts of rural electrification and clean cooking projects, local markets for electricity services, and project benefits for populations that have purchased systems or have adopted (or might adopt) service (box 4-1).

Identifying Evaluation Objectives

The objectives of any survey must be defined well in advance of its application. Surveys are designed to measure specific types of information. The types collected depend on the objectives of the M&E program. The objectives of countries, projects, and programs will differ. For example, a conventional power distribution project may be more concerned about identifying rural markets

Box 4-1. Steps of the socioeconomic impact survey

The general steps involved in developing and conducting the socioeconomic impact survey are as follows:

1. Identify evaluation objective.
2. Establish research design.
3. Identify sample population and interviewees.
4. Design questionnaire.
5. Implement survey.
6. Analyze results.
7. Feed results back into project planning and implementation.

Source: World Bank 2003.

for their services since their primary interest may be to increase sales. Development institutions, on the other hand, may have greater interest in a project's social development impacts. Finally, donor agencies and governments may be mainly interested in a project's impacts on society and lessons learned for projects elsewhere.

However, rural electrification and clean cooking M&E programs will not maximize their benefits if they focus on narrow objectives. Even successful projects that do not concern themselves with social development impacts may miss out on opportunities to gain a better understanding of the markets for their services. On the other hand, rural electrification projects with significant social and economic benefits that have significant financial losses due to poor policies will prove financially unsustainable and ultimately fail. Thus, it is critical to design the survey with multiple objectives in mind.

Establishing Research Design

Evaluation research for energy access is similar to other types of project assessments in several ways. Socioeconomic changes in the project areas must, in some way, be attributed to the energy access project, as opposed to impacts resulting from other interventions. The research design must therefore address how to isolate the impacts of energy access from other social infrastructure characteristics. For example, to assess the impact of rural electrification, the use of various appliances before and after electrification can be compared. Alternatively, one can examine households with and without electricity or clean methods of cooking that have similar socioeconomic characteristics.

Comparing energy-use patterns, social conditions, and level of economic development or well-being within two closely spaced periods of time will not provide a fair evaluation of the effects of energy access. Empirical evidence shows that social changes due to energy access tend to be incremental and often take longer than a few years to detect. Therefore, it is useful to consider beforehand the number of years over which follow-up M&E must be conducted to assess changes. Five years is probably a sufficient period of time between major surveys. For ongoing monitoring of project progress, two years between surveys is likely adequate.

Identifying Sample Population and Interviewees

It is usually difficult or cost-ineffective to measure the impacts of energy access on each individual, household, small business, and community institution that benefits from the project. Thus, impacts are often measured from a sample of households and extrapolated to the entire population, which the sample represents. The evaluation design must therefore ensure that the results are representative and can be generalized to the intended population. A wide body of literature is available on selecting representative samples (see, for example, Bernard 1995; Cochran 1977; Kish 1965; and Deming 1950). The methodology selected will depend on the local context, time and resource availability, and needs of the project. The principles discussed above concerning the identification of relevant social groups are equally applicable here.

The socioeconomic impact study questionnaire should obtain information on adoption of electricity, electric appliance use, and the social and economic impacts associated with access to electricity. For this type of survey research, questionnaires or schedules of questions must be designed to collect information at the individual, household, and small-business level. At the household level, information should be obtained from both male and female heads of households.[11] Collecting gender-disaggregated data is important for the following reasons:

- Empirical evidence shows that interviewing only male heads of households may not accurately represent all members of the household;
- Men and women have different roles in society and the household; thus, they are involved in different activities and have different needs and priorities;
- Women and men may benefit from rural development and infrastructure projects and programs to varying degrees and at different levels; and
- Researchers cannot understand the entire picture from only half the population (Range and Omondi 2000).

[11] For the purposes of this report, we assume that each household has one male (husband or male partner) and one female (wife or female partner) head of household unless the household is headed by only one adult, male or female, owing to the death of a spouse, divorce, separation, or single parentage.

The responses of males and females will be similar in some cases and differ in others. Ideally, in a dually headed household, the same set of questions should be asked separately of both the male and the female. The responses can then be disaggregated by gender to determine differences between the views of men and women. In households with a single head (male or female), the same set of questions should be asked of this person. In practice, however, this is both time-consuming and difficult. If the budget is available for such interviews, then it is recommended. However, some questions about the household will result in very similar answers. For example, it is doubtful that the estimation of family size will differ according to the respondent. Thus, after pilot-testing the questionnaire, the team should determine the questions to be asked of men and women separately.

One goal of the sample design is to determine the number of interviews needed for the evaluation of energy access projects. Sample size should be large enough to detect the impacts (i.e., changes in outcomes due to the intervention) that are statistically significant. As indicated, determining the sample size in practice depends on a number of factors. These include identifying the indicators; estimating the desired minimum detectable effect size (impact); determining the level of statistical significance (i.e., the sample should be sufficiently large to minimize the likelihood of detecting an effect that does not exist); determining statistical power (i.e., the sample should be sufficiently large to minimize the likelihood of not detecting an effect that does exist); and inter-cluster correlation. The simplified formula that can be used for sample-size calculation is this:

$$n_1 = \frac{(r+1)}{r} \cdot \frac{\sigma^2 \left(Z_\beta + Z_{\alpha/2}\right)^2}{D^2} \cdot \left(1 + \rho\left(H - 1\right)\right), \tag{4.1}$$

where n_1 represents the size of the smaller group (depending on the purpose, the treatment or control group could be smaller); r equals the ratio of the larger group to the smaller group (for equal-size treatment and control groups, $r = 1$; for a 60:40 ratio of treatment to control group, $r = 3/2$); σ is the standard deviation of the outcome variable; D represents the effect size (expected difference in outcomes between treatment and control groups); Z_β is the desired power (for 90 percent power its value is 1.282, which is fairly common); $Z_{\alpha/2}$ is the desired level of statistical significance (for a 95 percent confidence level in a 2-tailed test its value is 1.96, which is fairly common); ρ is the intra-cluster correlation coefficient (we can use a value of 0.03); and H equals the number of households sampled in each cluster (village) (we can use 20).

Let us assume that the outcome is the natural logarithm of per capita income with a standard deviation of 0.9 (the variable σ), and we expect an income growth of 15 percent as a result of the intervention ($D = 0.15$). Using these values in the formula and assuming equal-size group, we get the following;

$$n_1 = \frac{(1+1)}{1} \cdot \frac{0.9^2 (1.282 + 1.96)^2}{0.12^2} \cdot \left(1 + 0.03(20-1)\right) = 1{,}856.4 \approx 1{,}900, \quad (4.2)$$

and the total sample size equals (2 × 1,900) or 3,800.

Assuming a 60:40 ratio of treatment and control group, we get the following:

$$n_1 = \frac{(3/2+1)}{3/2} \cdot \frac{0.9^2 (1.282 + 1.96)^2}{0.12^2} \cdot \left(1 + 0.03(20-1)\right) = 1{,}547 \approx 1{,}600, \quad (4.3)$$

which is the size of the control group. The size of the treatment group is 2,400, while the total sample size equals (1,600 + 2,400) or 4,000.

One can adjust the sample size by non-response rate; that is, if we expect a 5 percent non-response during the interviews, the sample size should be increased by a factor of 1.05. For multiple outcomes, the sample-size calculation should be carried out for each outcome, and the actual sample size should be the largest size obtained from such calculations. In practice, sample sizes are usually limited by budget or other practical considerations. However, sample-size calculation gives the researchers an estimate of appropriate sample size.

After the sample size is determined, sample units (e.g., households) are geographically allocated in the study areas. For large studies, sample allocation is most commonly done in two major stages. In the first stage, primary sampling units (PSUs) (also called clusters) are randomly selected, which are usually villages, communities, or urban blocks. In the second stage, households (called secondary sampling units or SSUs) are randomly sampled, usually in equal numbers, from the PSUs. For large or nationally representative studies, sample distribution often includes stratification—dividing study areas into geographical regions. For example, to study the impacts of rural electrification for the whole country we may want to distinguish effects by major geographical regions (e.g., provinces). In stratified sampling, PSUs are first selected separately from each of the regions, and households are then selected from the PSUs.[12]

Weighting

Weight or sampling weight is an adjustment factor applied to each observation of the data during analysis to adjust for differential selection probability of sample units and make the findings representative of the underlying population. In general, the weight is the inverse of the probability of selecting a sample unit, or an indication of the units of population unit represented by each sample unit. This weight is also called design weight or base weight.

Let us consider a two-stage sampling process where PSUs are selected in the first stage from each stratum and households are selected in the second stage from each PSU. So, the selection probability of a PSU in the first stage is expressed as follows:

$$p_1 = \frac{m_h N_{hi}}{N_{hi}}, \tag{4.4}$$

where m_h is the number of PSUs selected from stratum h, N_{hi} is the number of households in PSU i of stratum h (usually obtained from a secondary source such as a census), and N_h is the number of households in stratum h (usually obtained from a secondary source such as a census). The selection probability of a household in the second stage is as follows:

$$p_2 = \frac{n_{hi}}{N'_{hi}}, \tag{4.5}$$

where n_{hi} is the number of households selected from PSU i of stratum h, and N'_{hi} is the number of households obtained from listing activity in PSU i of stratum h. In most cases, $N_h = N'_{hi}$. So, the overall selection probability of a household is given by,

[12] Various rules apply to determining the number of PSUs to be selected from each stratum (e.g., proportional allocation, equal allocation, and optimum allocation). A detailed discussion of such rules is beyond the scope of this study.

$$p_{hij} = p_1 \cdot p_2 = \frac{m_h N_{hi}}{N_h} \cdot \frac{n_{hi}}{N'_{hi}} . \tag{4.6}$$

Finally, the sampling weight is given by the following:

$$w_{hij} = \frac{1}{p_{hij}} . \tag{4.7}$$

In reality, weight calculation often takes other, more advanced factors into account (e.g., post-stratification and non-response), which are not covered here.

Questionnaire Design

After the broader research questions have been identified, the socioeconomic questions can be designed. As they are developed, one should keep in mind the priority needs identified by the communities during the participatory research. For rural electrification, several general categories of questions are important to address. These include questions designed to assess whether market conditions are right for implementing or expanding projects or programs, the socioeconomic impacts of rural electrification, and how the program will affect poverty and gender issues (box 4-2).

The questionnaire content should always be directed by the project's objectives and needs. Most surveys include some standard types of information. Generally, the socioeconomic survey questionnaire consists of questions designed to collect data from respondents on the amount of energy consumed for each end use, as well as factors that influence consumption, energy expenditures, and the development impacts of electricity. If questions jump from one topic to another, respondents may become confused and produce unreliable answers. Thus, each set of questions should be sequenced to follow the thought processes of respondents. Each topic must be included in both the baseline survey conducted before electrification and in follow-up surveys to assess the impacts of electrification. The subsections below describe the types of information that might be covered (see Annex C, for example).

Box 4-2. Possible research topics for questionnaire

The questionnaire design should cover the following socioeconomic issues:

- Socioeconomic profile of actual and potential beneficiaries/customers.
- Fuel and energy use prior to improved electricity services, including energy from all sources (e.g., candles, biomass, batteries, the electric grid, and diesel generator sets).
- Monthly expenditures on fuels and energy, by source.
- Potential and actual willingness to pay for energy services, by application.
- Energy use as it relates to substitutes for improved services provided by modern energy access (kerosene, candles, and others).
- Reasons for not connecting to the grid or purchasing improved energy devices.
- Barriers to the adoption of improved electricity or clean cooking technologies and services.
- Incentives to overcome barriers to adopting improved electricity or clean cooking technologies and services.
- Appliances in rural households, including those with and without electricity or devices for clean cooking.
- Time use of males and females as it relates to existing use of energy or appliances.

Source: World Bank 2003.

Socioeconomic and Demographic Information

Background information on the respondent and family members is very important. This information should include the respondent's gender and whether the respondent is the female or male head of household. In addition, the demographic profile of individual household members can be collected, including age, sex, education level, school enrollment among school-age children, ability to read and write, and occupation. With such information, the research team can assess the impacts of electricity on different members of the household or community. For example, knowing the literacy level of each household member before and after adoption of electricity or clean cooking methods will enable the team to assess whether electricity has had any impact on the literacy of different household members.

Household Income

One of the most important types of socioeconomic information from any survey is household income. Generally, questions concerning household income are asked in a section separate from that on socioeconomic background. The reason is that income requires a series of interrelated questions to arrive at an accurate figure, especially in rural areas where the majority of households may earn income from agriculture. Household income can be used to measure the overall economic well-being of the household. Empirical evidence shows that a household with more adult family members usually has higher household income, while those with many small children or headed by a single woman tend to have lower income. Household income questions must address sources of income by family member. Such information will enable the researcher to link any increase or decrease in income from each specific activity to whether electricity has contributed to these changes.

Control over access to financial resources within the household is often a complex issue. It should not be assumed that women and men within the same household have equitable access to financial resources. Thus, it is important to ask income questions separately of the male and female members of the household. It is sometimes difficult to get reliable information on income in questionnaires, as people are usually reluctant to discuss this subject. This issue can be resolved during the pre-test of the survey instrument.

Physical Housing Information

Household energy surveys should include questions related to the housing unit's physical structure, such as type of dwelling (e.g., apartment or attached, semi-detached, or detached home), occupancy (year-round or seasonal), and property status (ownership, rental, or rent-free). Questions should also gauge the household's accessibility to major infrastructure—such as schools, health centers, water supply systems, roads, and main access to the home—to provide complementary information in order to evaluate the impact of rural electrification.

Households with Businesses

In many rural households, male and female household members engage in home business activities. This means they use part of their home for income-generating activities. Thus, a set of questions must be formed to collect detailed information on these activities. Questions might include type of business, productivity and profitability, who is in charge of and engaged in the business, and whether electrification directly or indirectly impacts these business activities. Impacts of electrification on home businesses can be measured in terms of changes in production or efficiency, increased ability to work or operate the business for longer hours, and changes in income or revenue from the business. Knowing whether households engage in business activities at home and the type of business also provide valuable market data for project managers and electricity service providers, allowing them to assess potential productive uses of electricity in the community.

Existing Types of Energy Used in the Household

It is critical to understand what fuels and energy sources are being used in the project area, both before and after project implementation. This will assist in deciding on which improved energy-access technologies and services the project should promote and understanding their impacts (box 4-3).

Box 4-3. Typical fuels in rural areas of developing countries

The survey questionnaire needs to identify the fuels or energy sources and sources of electricity used before and after electrification, including all fuels used for lighting, appliances, and businesses. Those typical of rural areas in developing countries are as follows:

- Candles;
- Fuelwood, animal dung, and other biomass;
- Kerosene (wick and hurricane lamps) for lamp lighting;
- Biogas;
- LPG;
- Diesel (wick and hurricane lamps) for lamp lighting;
- Torch;
- Dry-cell batteries;
- Car batteries;
- Household-owned electric generator;
- Electric generator owned by neighbor;
- Electricity from privately owned mini-grid or village/community grid;
- Electricity from national, regional, or town grid;
- Pico- and micro-hydro electric generator;
- Solar PV home system; and
- Various types of cooking devices.

Source: World Bank 2003.

For example, empirical evidence from past surveys on rural electrification suggests that, even after grid-connected electricity becomes available in a community, a significant number of households may not adopt the service right away. This is true for a variety of reasons. First, electricity is often expensive, even for many wealthier families, precluding its use for activities that use large quantities (e.g., cooking). Second, electricity must be used with appliances that can be costly; thus, appliances are usually acquired incrementally. Third, the quality of grid electricity service is often poor. Fourth, house-wiring problems and costs may limit the use of appliances. Finally, many people may prefer to continue using the energy sources with which they are familiar. Such reasons for delaying electricity adoption from grid-based systems also hold true for systems based on renewable energy.

Energy Consumption and Expenditures

Once the types of fuels and energy sources before and after electrification are identified, the next step is to assess the quantity consumed and associated expenditures for each energy source. This can be done by asking questions concerning average quantity of energy consumed per month by purpose, monthly expenditures on each fuel, and the average price paid for it, either in cash or labor used to collect it.

Knowing the quantity of energy consumed and its associated expenditures enables the team to evaluate and compare the costs of various types of energy. In this way, the expenditures and use can be compared both before and after the electrification or clean cooking project. Quantitative data on energy consumption and expenditures can be analyzed in conjunction with expenditures and use of particular appliances to quantify the quality and cost of energy use for particular applications. One technique used to measure the benefits of having electricity is to examine the price and quantity of lighting for a household before and after obtaining electricity. This generally involves a switch from the use of kerosene lamps to electric lights or from traditional to better stoves. Also, what people consider "expensive" for each activity can often be very telling, and can vary greatly by gender.

Reasons for Adopting Electricity Service

Understanding why customers do or do not adopt electricity or methods of clean cooking can be useful for finding ways to improve services, formulating marketing strategies, and developing ancillary programs to widen the use of electricity service. Often, this relates to a household's perception of what is "expensive." As discussed above, evidence has shown that, once electricity or clean cooking techniques become available in a community, not all potential customers adopt it. Knowing the barriers that prevent potential customers from adopting electricity will enable project managers and service providers to increase customer satisfaction and connection rates, which can increase the company's revenues.

Some common barriers to adoption of electricity or methods of clean cooking involve higher costs (e.g., more expensive stoves, the necessity of house wiring, and related expenses). Other survey questions may be focused on assessing strategies to promote energy access and increase adoption or connection rates.[13] For example, to help potential customers overcome upfront costs, rural electrification programs may decide to include a credit program for connection costs, and the survey can reveal whether households might take advantage of such a program. Questions concerning attitudes toward electricity can also be used to assess the characteristics of customers versus noncustomers, providing insight into the reasons for adopting electricity service.

Quality of Electricity Service

It is quite important to understand the quality and reliability of the electricity service being provided to consumers and how it is perceived by various social groups. For example, a community may have access to the electric grid, but the service is unreliable. In other cases, off-grid systems have been installed, but have not been properly maintained, leading to operational problems. Elsewhere, a small hydropower generator may supply electricity, but households may only use electricity during the rainy season or for a portion of the year.[14]

As a result, customers continue to rely heavily on traditional fuels (e.g., candles, kerosene, or rechargeable batteries) for services that are inferior to those

[13] Information gathered from the participatory assessment can be useful in finding out why some households choose to adopt new electricity services while others do not and understanding the characteristics of nonparticipants. This information can then be used in designing the survey questions.

[14] Recent statistics from China's Ministry of Agriculture indicate that approximately 87 percent of rural farm households are electrified; for some, however, supplies are limited to the rainy season (6–7 months of the year).

provided by electricity. To collect information on electricity services, questions must be designed to measure the quality of services, such as frequency and length of electricity outages and how well the system or equipment is maintained (box 4-4).

The adoption of methods for clean cooking also involve a similar set of issues compared to electricity. These might include the reliability and convenience of using a new type of stove or combination of stove and fuel. For example, a household adopting an LPG stove must have a reliable supply. Some of the main problems of wood stove adoption have included underperformance caused by maintenance issues.

Other Measures Important for Energy Use

Many other measures are important for energy use. Ownership of appliances leads to more use of electricity and greater benefits. In households with electricity, time-use patterns also change, with more socializing in the evenings, more studying, and increased entertainment through use of radios and television sets.

Box 4-4. Assessing the quality of electricity service

Questions designed to collect information used to measure the quality of electricity service include the following:

- Number of hours per day and number of days per week household/customer has access to electricity.
- Number of months per year the sampled household/customer has access to electricity.
- Number of power outages during the past month.
- Average length of time each power outage lasts.
- Whether the sampled household experiences any drop in voltage (dimming of lights) or unscheduled power cuts.
- Frequency of system/equipment breakdowns.

Source: World Bank 2003.

Appliance Ownership and Electricity Use

Appliance ownership and use greatly affect power supply and load and thus the impact of electricity for rural households and the financial viability of the electricity provider. Empirical evidence shows that the pattern of appliance acquisition and ownership among rural households after electrification is an incremental process. Typically, household customers acquire electric lighting as the first application (box 4-5); subsequent appliances usually include an electric fan, small radio and tape cassette player, and television set or other video equipment. Small business applications outside the home typically include lighting and fans, electrification of mechanical activities, and food processing and preservation. Understanding how decisions are made to purchase these items is quite important.

Appliances can serve multiple functions. For example, an electric fan not only cools the air and provides comfort; it also blows mosquitoes and other disease-bearing insects away from users. Radio and television provide useful news and information, as well as entertainment.

Box 4-5. Impacts of electric lighting

Virtually all households with electricity use it for lighting. To measure the impact of electric lighting on rural households, it is important to know the number of lighting appliances used by customers before and after electrification. These appliances should include such non-electric equipment as candles, simple kerosene wick lamps, regulated wick lamps (hurricane lanterns), and pressurized kerosene lamps for households without electricity. For households with electricity, lighting appliances would include incandescent, fluorescent, and compact fluorescent lamps (CFLs). The questionnaire must also include length of time that each lamp is used in a typical day.

With this information, researchers can make comparisons for rural households with and without electricity with regard to the price and the quantity of lumen hours utilized. Typically, households with electricity consume more than 20 times more lighting than households with kerosene lamps, but the price per unit of light is substantially lower. Such information can be used to quantify the benefits of electric lighting for rural households using methods involving willingness to pay.

Source: World Bank 2003.

The survey questions should include all types of appliances commonly used among rural households in the project area, as well as the number of appliances owned by each customer. Because households may own more than one appliance of the same type, questions should check the number of appliances owned. Information on power tools and motive power equipment commonly used for income-generating purposes should also be collected. Also, it is important to know the wattage of each appliance, intensity of usage, and associated electricity cost. As an example of the utility of this information, the impact of electricity on the household can be measured by comparing cost and number of hours spent watching television powered by a car battery with those made possible by having a grid or a solar PV system.

Time Use

Changes or differences in time use for families adopting electricity or methods of clean cooking can be indicators for their impact on the lives of the rural poor and women. The quantification of the way men and women of different socioeconomic classes spend their time helps us understand the various roles, responsibilities, and burdens these groups face. With this knowledge, we can assess whether improved electricity or clean cooking services have improved the ease, efficiency, or productivity of these activities and whether additional time has been freed up for other desired activities.

For those studies interested in gender differences, it is worthwhile to ask the same set of questions to both male and female respondents. For example, fuelwood collection has traditionally been considered women's activity. However, recent studies show that men are increasingly involved in fuelwood collection. Women tend to gather fuelwood near the home, but rising resource scarcity is driving families to either travel farther to collect fuelwood or to buy it in the market. These latter activities tend to be men's responsibilities. Thus, time and resources permitting, the survey of time use would contain the same set of possible activities for both men and women.

Consumer Attitudes toward Electricity and Clean Cooking

Since the main objective of the survey is to measure the impact of electricity and clean cooking on the lives of rural households, the survey should contain a series of attitude questions on electricity and other household energy sources.

The survey questions might contain information on the respondents' fuel preferences, attitudes toward various energy sources, attitudes toward renewable energy technologies, perceived costs and benefits of electricity, and willingness to pay for electricity services. These questions can be developed in the form of statements with which the respondents are asked to agree or disagree.

The participatory assessment may provide a valuable source of information concerning which attitude questions are important to include in the quantitative survey. This might possibly address the perceived value of electricity in terms of productive uses, education, health, and feelings of safety, among other issues. For gender analysis, these questions should be asked of both the main male and female if budget and time are sufficient.

Additional Aspects of Conducting the Survey

Qualified and well-motivated field staff and enumerators are critical to the success of any survey. The field staff should be organized into teams. Each team should consist of 3–4 staff members, including a supervisor, who will provide oversight. Depending on the country's customs, the staff will involve both male and female enumerators. The number of persons on a team is generally based on the assumption that one enumerator can complete 2–3 household interviews per day; of course, this will depend on the length of the survey interview and number of household members that must be interviewed during the course of the survey.

Ideally, the interviewing team will consist of two enumerators per household for the purpose of interviewing men and women. The administration of the questionnaire can vary quite a bit because of local customs. In some cases, it is essential to have both male and female enumerators present in the same household for the interview. In others, the questions can be asked in a group setting, with the appropriate responses coming from the individual that knows the most about the issue under discussion. In still others, men and women will respond adequately to interviewers of either sex. Successful interviewing strategies are developed as part of the pre-testing of the questionnaire.

Information gathered during the socioeconomic survey can be analyzed at a number of levels, using a variety of statistical techniques. An in-depth analysis, which involves the use of social or economic valuation techniques, can also be conducted. This can provide useful information to project managers and donor agencies in deciding on changes to improve project efficiency and effectiveness and planning for future projects. At a minimum, the results of the analysis will be presented in the form of tables, and a report will be written that interprets and provides information and policy conclusions for projects and policy planners. In Part 2 of this handbook, we examine some of the more advanced measures of the impact of electricity for development, including how to monetize the results of energy surveys.

PART 2

Benefits Estimation

Chapter 5

Electrification Benefits: Consumer Surplus Approach

The consumer surplus approach is based on the value that consumers place on various energy services, including basic lighting, entertainment, appliance use, and space conditioning, among others. The basic framework is that consumers also pay for such services as lighting before they adopt electricity. This service is provided by other energy sources, such as kerosene or candles. Before households have electricity, their lighting costs using kerosene or candles are fairly expensive. As a result, they use little lighting, consuming it sparingly. After adopting electricity, the price of lighting drops by a factor of as much as 50–100 times. Because electricity is cheaper, households purchase much more light. It is assumed that these are two points on a demand curve for lighting. Such light is valued by consumers for a variety of activities. Since it is hard to value the individual contributions to such activities, the consumer surplus approach values them together as the willingness to pay for lighting services.

The sections below explain how to estimate consumer surplus through the use of household surveys. For each energy service, the current literature, estimation techniques, and required survey questions are briefly reviewed.

The Switch to Electric Lighting

After adopting electricity, households immediately begin using electric lamps. Kerosene lamps or candles are expensive to use and typically illuminate only a small area with a dim light. Electric lamps are much more efficient in converting energy into light and are less expensive to use. Typically, a household that switches from candles or kerosene to electricity expands its lighting use by 100–200 times compared to the levels prior to electricity access. This far superior lighting covers a much larger area, is soothing to eyes, and provides a comfortable environment for reading or close work. With better lighting, a wider range of activities is possible for households, including studying, reading, making handicrafts, safely moving about the house, doing chores, and socializing.

A wide range of studies confirms that the adoption of electricity results in a higher level of household lighting use. Nearly all households without electricity use kerosene or candles for lighting, and the numbers add up. For example, the energy poor in Africa spend about US$17 billion a year on costly, inefficient kerosene-based lighting, which offers poor-quality light, poses fire hazards, and pollutes the indoor environment. Making the switch to higher-quality, more efficient electric lighting enables households to read and study during evening hours, increase productivity, and raise incomes and quality of life (box 5-1).

The positive benefits of better lighting have been documented by many studies. For example, a study in Rwanda indicates that adopting electricity increases the number of lighting hours per day (Bensch, Kluve, and Peters 2011). These finding are corroborated by surveys conducted in Bangladesh (Barkat et al. 2002) and the Philippines (World Bank 2002a). Another electrification study

Box 5-1. Making the switch: Benefits of electric lighting

Households that switch to higher-quality, more efficient electric lighting can read and study during evening hours, increase productivity, and raise incomes and quality of life. Compared to candles or kerosene lamps, commonly used by households without electricity, electricity converts energy into lighting more efficiently. A candle or kerosene wick lamp emits about 12 lumens (a measure of brightness), a hurricane kerosene lamp 32 lumens, and a 60-watt lightbulb 730 lumens. Burning kerosene in a hurricane lamp for 4 hours a night yields only 4 klmh per month. Using a single 60-watt lightbulb 4 hours a day, a household consumes about 260 klmh of light per month. Electric lighting can actually consume less family income than lighting with kerosene. The energy poor in Africa spend about US$17 billion a year on costly, inefficient, and polluting kerosene lamps and other fuel-based lighting sources, which provide poor-quality light while posing fire hazards.

Sources: Lighting Africa (https://www.lightingafrica.org/); Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1998; O'Sullivan and Barnes 2007.

in rural Bangladesh finds that study time increases by 22 minutes per day for boys and 12 minutes per day for girls (Khandker, Barnes, and Samad 2012). Similarly, a study in rural India finds that household adoption of electricity increases boys' and girls' daily study time by 12 minutes and 14 minutes, respectively (Khandker et al. 2014). Finally, in Bhutan, having electricity increases study time by 10 minutes per day for all children (Kumar and Rauniyar 2011).

Quantitative Technique

The challenge, of course, is turning these impact findings into monetary values. This can be accomplished by applying the technique for estimating consumer surplus. This method does not measure the minutes of study time improved or the benefit of reading or doing handicrafts during evening hours. Instead, the increased value for all of these services is rolled into the benefit of household lighting derived from a consumer demand curve for lighting.

The net benefit of electric lighting, compared to kerosene lighting, can be measured using the consumer surplus approach. The benefit is given by the previous general equation (3.2), rewritten as follows:

$$CS_{LIGHT} = \left(P_k - P_E\right) * Q_K + \tfrac{K}{\eta+1}\left(Q_E^{\eta+1} - Q_K^{\eta+1}\right) - \left(Q_E - Q_K\right) P_{E}, \qquad (5.1)$$

where P is price of electricity or kerosene and Q is the quantity of lighting produced by kerosene or electricity.

Measuring Variables

Household surveys are required to measure both the prices and quantities of the fuels used. The surveys must contain questions on the actual use of lighting fuels before and after a household has electricity. For a survey conducted during the same time period, with proper controls, households with and without electricity can be compared.

Figure 5-1 shows the basic survey questions that must be asked to obtain the necessary information on household lighting needed to calculate the consumer surplus for lighting. In this example, questions are asked on each type of light bulb in the household and its use each day. This information must be collected

Figure 5-1. Questions on kerosene and electric incandescent lamps

Incandescent bulbs in grid-connected household (only bulbs used for more than 30 minutes per day)			
inc1	**25 W**	**inc1**	
inc1.1	→ Number of bulbs	inc1.1	
inc1.2	→ Total hours used per day	inc1.2	
inc2	**40 W**	**inc2**	
inc2.1	→ Number of bulbs	inc2.1	
inc2.2	→ Total hours used per day	inc2.2	
inc3	**50 W**	**inc3**	
inc3.1	→ Number of bulbs	inc3.1	
inc3.2	→ Total hours used per day	inc3.2	
inc4	**60 W**	**inc4**	
inc4.1	→ Number of bulbs	inc4.1	
inc4.2	→ Total hours used per day	inc4.2	
inc5	**100 W**	**inc5**	
inc5.1	→ Number of bulbs	inc5.1	
inc5.2	→ Total hours used per day	inc5.2	
nea6	**Kerosene lamps**	**nea6**	
nea6.1	→ Number	nea6.1	
nea6.2	→ Hours used per day	nea6.2	
exp7	**Expenditure**	**exp7**	
exp7.1	→ Kerosene expenditure per day	exp7.1	
exp7.2	→ Electricity expenditure per day	exp7.2	

Sources: World Bank 2002a; Annex A.
Note: Generally, the bulbs must be those typically used by households in the survey. It is better to predefine the bulbs in use rather than ask households about the wattage because the latter method makes it confusing for respondents. For PV or battery-operated lamps, separate modules defining the typical lamps used with those electricity sources may be necessary.

for every type of fuel use. For example, the survey must contain similar questions for kerosene lamps, candles, florescent lamps, LED lights, and any other lighting source. Flashlights and other similar lighting appliance information can be collected, but the contingent valuation (CV) method is based only on general household lighting appliances.[15] The appliance and lamp questions can be either within or outside of the individual energy sections. The key to calculating CV for lighting is to obtain the use of each lamp or appliance in hours per day.

Responses to the questions in figure 5-1 can be used to calculate the right-hand side variables in equation (5.1), as follows:

Q_K = Lighting quantity from kerosene (kilolumen-hours/day), calculated from **nea6**,[16]

$P_K = \frac{exp7.1}{Q_K}$ = Price paid for kerosene lighting ($/kilolumen-hours),

Q_E = Lighting quantity from electricity (kilolumen-hours/day), calculated from **inc1-inc5**,[17] and

$P_E = \frac{exp7.2}{Q_E}$ = Price paid for electric lighting ($/kilolumen-hours).

Since households use kerosene and electricity for other purposes beyond lighting, the calculation of consumer surplus must exclude all other such uses. This is done by using the information on kerosene and kerosene lamp use in the survey to calculate the amount of lighting produced using kerosene as a fuel (figure 5-1, Annexes A and B). The conversion factors for lighting kilolumen-hours involving kerosene and electric lamps are found in Annex D. The resulting consumer surplus is the benefit from switching from traditional to more modern forms of lighting made possible by having electricity.

[15] Annexes A and B provide further information on this type of household energy survey question.
[16] Multiplying kerosene consumption per day (in liters) by a conversion factor yields the kilolumen-hours emitted by specific kerosene lamps. This then is multiplied by the number of hours the lamps are used per day. This calculation must be done for each kerosene lamp and then summed to get the total kilolumen-hours for all kerosene lamps.
[17] Electricity consumption per day (in kilowatt hours) is multiplied by a conversion factor to obtain the kilolumen-hours provided by specific electric lamps. This then is multiplied by the number of hours the lamps are used per day to obtain lighting levels for that particular lamp. This calculation must be done for each electric lamp and then summed to get the total kilolumen-hours for all electric lamps.

Use of Radio and TV

The use of radios and TVs are other services that are expected to increase once households adopt electricity. Both radio listening and television watching require some form of electricity. For those households without grid electricity, the use of battery-operated radios is quite common. D-cell batteries are a quite expensive form of electricity supply, typically costing about US$40 per kWh. This translates into listening hours that are quite expensive. Most television sets require too much power to be operated by D-cell batteries. In such countries as Peru, it was found that people often operate TVs off of car batteries. Once a household adopts electricity from the grid, the cost per listening hour falls, in turn, making listening and viewing hours affordable. This means that the availability of electricity makes it possible for households to listen to more radio and watch more TV, in turn, giving them access to more information on such topics as national news, health, nutrition, lifestyle, business, and social awareness. Also, both radio and television are main sources of entertainment.

A study in Brazil shows that access to TV can affect women's preferences in fertility (la Ferrara, Chong, and Duryea 2008). Another study in India finds that watching TV improves women's status in the household (Jensen and Oster 2007). A good summary of how consumer surplus for radio and television can be calculated can also be found for the Philippines (World Bank 2002a) and Peru (Meier et al. 2010).

Quantitative Technique

The shift from battery-operated radios or TVs to plug-in radios and TVs is similar to the case of household lighting. Households switch from a high cost per viewing or listening hour to a lower cost with the plug-in appliances. Thus, the benefits of grid electricity adoption results in improved entertainment and news. The benefits of expanded use of radio and TV can be approximated through the use of the consumer surplus approach. The assumption is that households without electricity, because of their reliance on batteries, are willing to pay a high price for radio listening and television viewing hours. On the other hand, for households with electricity, the price of listening and viewing is considerably lower. As a result, switching from battery-powered radio or TV to plug-in electric radios or TVs would result in expanded listening or viewing hours. The assumption is a valid demand curve for radio listening and television viewing.

The net benefit of using electricity instead of a battery for radio listening can be measured using the consumer surplus method, as follows:

$$CS_{RADIO} = (P_{RB} - P_{RE})^{*} Q_{RB} + \tfrac{k}{\eta+1}(Q_{RE}^{\eta+1} - Q_{RB}^{\eta+1}) - (Q_{RE} - Q_{RB}) P_{RE}, \qquad (5.2)$$

where Q_{RB} represents the time spent listening to radio using a battery (hours per month), P_{RB} equals the price of listening to radio using a battery ($ per hour), Q_{RE} is the time spent listening to radio using electricity (hours per month), and P_{RE} is the price of listening to radio using electricity ($ per hour).

Similarly, the net benefit of watching TV using electricity from the grid or a battery can be measured using the consumer surplus technique, as follows:

$$CS_{TV} = (P_{TB} - P_{TE})^{*} Q_{TB} + \tfrac{k}{\eta+1}(Q_{TE}^{\eta+1} - Q_{TB}^{\eta+1}) - (Q_{TE} - Q_{TB}) P_{TE}, \qquad (5.3)$$

where Q_{TB} represents time spent watching TV using a battery (hours per month), P_{TB} equals the price of watching TV using a battery ($ per hour), Q_{TE} is the time spent watching TV using electricity (hours per month), and P_{TE} is the price of watching TV using electricity ($ per hour).

Measurement of Benefits

The measurement of radio and television use can be measured by asking questions about the devices (figure 5-2). This would mean taking an inventory of each appliance and how much each is used over an appropriate time period.

Figure 5-2. Questions on radio use

ea1	**Radio (Grid electricity)**	**ea1**	
ea1.1	Number	ea1.1	
ea1.2	Total watts	ea1.2	
ea1.3	Hours used per day	ea1.3	
ea2	**Radio (Battery)**	**ea2**	
ea2.1	Number	ea2.1	
ea2.2.1	Total batteries used over 6 months	ea2.2	
ea2.2.2	Total cost of batteries used over 6 months		
ea2.3	Total hours used per day	ea2.3	

The variables in equation (5.2) can be calculated based on the time spent listening to the radio vis-à-vis the cost of that listening. The household cost of listening to battery-operated or plug-in radios can be calculated by multiplying the hours used per day by the total wattage of all radios in the household. The result is then multiplied by the price of electricity. For batteries, the typical expense can be calculated by the cost of the total number of batteries used for listening to radios, and this can be divided by the number of listening hours, providing the cost per listening hour for battery-operated and plug-in radios.

Television viewing is based on a technique similar to that used for radio listening. In most household surveys, some households have battery-operated televisions. Thus, the survey must be designed to capture the operating hours of both battery-operated and plug-in TVs. Of course, in nearly every developing country, grid-operated televisions are the most common; otherwise, they can be operated from solar home systems (SHSs), car batteries, or even the more commercially available D-cells.

Assessing the use and cost of viewing battery-operated televisions is less straightforward than for televisions with electricity from a distribution grid system. The reason is that households use batteries for a variety of purposes, and it is necessary to obtain information specifically for the use of the television. For this, two approaches are provided. The first approach (general questions) is the minimum necessary for assessing the household cost per viewing hour. The second approach (Peru case) is a bit more detailed and will provide better results, but the questions are somewhat more complex (figure 5-3).

The questions in figure 5-3 can be used to construct variables for equation (5.3). These variables can be calculated as follows:

Q_{TB} = Q4.11*30 (for households without electricity),

P_{TB} = Q4.12/ Q_{TB},

Q_{TE} = Q4.11*30 (for households with electricity), and

P_{TE} = (Q4.13*Q4.11*30/1000)*Q4.14/Q_{TE} .

Figure 5-3. Questions on TV use

General questions	
Q4.11	(For all households) How many hours per day TV is watched in the household? (hours)
Q4.12	(For households without electricity) How much does the household spend on the batteries used in TV? ($ per month)
Q4.13	(For households with electricity) What is the capacity of the TV? (W)
Q4.14	(For households with electricity) What is the electricity tariff? ($ per kWh)

Peru survey (More general questions on appliances)

	343A. Does the household use the following electric appliances, which are powered by electricity from a car battery?			343B. How many of each appliance does your household have?	343C. What is the average wattage rating of the appliance? Note: Estimate the average wattage if more than one appliance in use.	343D. What is the sum of all hours for all appliances used during the last 24-hour period? Note to enumerators: If the household has more than one appliance of this type, ask the respondent about the use of each appliance in the household and sum the total hours that the appliances are used in the last 24 hours.
				Code: Enter number of appliances or if do not use enter "-7."	Code: Enter the average number of watts of appliances or if do not use enter "-7."	Code: Enter the number of hours of use with fraction or if do not use enter "-7."
		Yes	No			Hours Minutes
1	Radio	1	2			
2	Sound equipment	1	2			
3	TV, black-and-white	1	2			
4	TV, color	1	2			
5	Video recorder	1	2			
6	DVD	1	2			
7	Others (Specify)	1	2			

Once again, the procedure is to use the questions on battery and plug-in televisions to uncover a demand curve for television viewing. Those households with batteries will watch television less than those with plug-in models powered by the grid. The reason is that the cost per viewing hour is higher for those with batteries. Once the demand curve is created, consumer surplus can be estimated as described in equation (5.3). This is the benefit of switching from batteries to grid electricity for TV viewing. It is not necessary for all households without grid to use batteries for calculating the consumer surplus of television viewing. However, care should be taken not to attribute the demand curve to all income classes if only households in the highest income groups with electricity purchase and watch television.

The consumer surplus for television viewing requires questions on viewing hours for those with grid electricity and alternatives, such as car batteries. Findings from the National Survey of Rural Household Energy in Peru indicate that the consumer surplus for television viewership made possible by grid electricity ranges from US$3 for black-and-white (B&W) TV to about $10 for color sets (Meier et al. 2010). The reason for the difference is due, in part, to the superior experience of watching color television and that poorer people tend to watch B&W television (box 5-2).

Use of Mobile Phones

Once households adopt electricity, the use of mobile phones is expected to increase. When households have electricity, they save time and money in charging their mobile phones. For households without electricity, household members often travel 1–2 km—usually to a market with electricity—to have their mobile phones charged. They pay a fee of up to US$0.25 per charge. Once households have electricity, they can save travel time by charging their phones using in-home power outlets. This costs a fraction of the fees paid for charging them in shops. The convenience and low cost of charging cell phones mean that households with electricity can be expected to use mobile phones more than their counterpart households without electricity.

In developing countries, mobile phones have brought transformative changes to people's lives. Mobile phones keep people connected with distant friends and relatives. They can be used to keep track of family members, reducing

Box 5-2. Calculating consumer surplus for watching TV in Peru

The consumer surplus technique was used in Peru to calculate the benefits of watching TV, using data from the National Survey of Rural Household Energy. The survey was jointly conducted by the Ministry of Energy and Mines and the World Bank in 2005, with financing for the survey fieldwork provided by the Ministry of Energy and Mines and that for the survey design and final report preparation provided by the World Bank's Energy Sector Management Assistance Program (ESMAP).

In estimating consumer surplus for television viewing, the welfare outcome is viewing hours. The assumption is that non-electrified households, because of their reliance on batteries, pay a higher price for viewing hours. For households with grid electricity, the price of watching TV is considerably lower. As a result, switching from a battery-powered TV to a plug-in set powered by electricity would result in extended viewing hours.

Table B5-2.1 shows the viewing hours and costs of the three main television types: black-and-white (B&W) powered by car batteries, B&W plug-in, and color plug-in. The cost reductions resulting from switching from battery-powered TVs to B&W and color plug-in TVs are 0.131 (= 0.16 – 0.0288) Soles per viewing hour and 0.115 (= 0.16 – 0.0450) Soles per viewing hour, respectively.

Table B5-2.1. Cost and viewing hours for television

Factor	Car battery, B&W TV	Grid, plug-in B&W TV	Grid, plug-In color TV
Viewing (hours/day)	2.81	2.59	6.83
Viewing (hours/month)	87	80	212
Power rating of TV (W)	24	48	75
Energy consumption (kWh/month)	2.1	3.9	15.9
Cost (Soles/month)	13.6	2.3	9.5
Cost (Soles/viewing hour)	0.16	0.0288	0.0450

Taking into account the total monthly hours, the monthly benefit of television viewing (consumer surplus) is estimated at 10.48 Soles per month for B&W TVs and 24.38 Soles per month for color TVs. We can also calculate the net benefit of switching from plug-in B&W TVs to plug-in color TVs (consumer surplus), which is 13.9 Soles per month.

Source: Meier et. al. 2010.

worries when they are away for periods of time. They also make it possible for people to inquire about markets for both agricultural and non-agricultural goods and services.

Many developing countries are using mobile phones increasingly for making financial transactions. In Bangladesh, for example, bKash is the country's largest mobile phone–based financial service. Within 30 months of its 2011 launch, bKash reached 11 million customers (Chen and Rasmussen 2014). In the Philippines, the local government of Quezon City uses mobile money to manage payrolls and distribute welfare benefits (USAID 2013). In Pakistan, a local government and mobile carrier cooperated to create a mobile program that sends farmers text or voice messages about crop prices, market access, and disease prevention (USAID 2014a). In Mozambique, some farmers save mobile money during post-harvest periods in order to have money available to pay for fertilizer during the following season (USAID 2014b). In Ghana, the Grameen Foundation's Mobile Midwife program sends women texts and voicemails regularly with advice in their language during pregnancy and the first year of the child's life (UN Foundation 2015). Thus, with increased access to mobile phones, people in households with electricity can access such benefits for longer periods of time compared to those without electricity. This increased use of mobile phones means greater benefits from the use of their phones.

Quantitative Technique

The benefits of mobile phone use for households with electricity can be estimated using the consumer surplus approach. The method is similar to the ones used to estimate the benefits of radio listening and television viewing. The assumption is that households without electricity are very careful in the use of their mobile phones because of the high price they pay for each hour of use due to higher charging costs. For households with electricity, the price of using mobile phones is much lower. Therefore, such households tend to use their phones more frequently for all types of services, which, in turn, means an increased value for consumers.

The net benefit of mobile phone use for households with and without electricity can be calculated using the technique of consumer surplus. The equation for consumer surplus of mobile phone use is as follows:

$$CS_{MOBILE} = (P_{MN} - P_{ME}) * Q_{MN} + \tfrac{k}{\eta+1}(Q_{ME}^{\eta+1} - Q_{MN}^{\eta+1}) - (Q_{ME} - Q_{MN})P_{ME}, \quad (5.4)$$

where Q_{ME} represents the time spent by all members of households with electricity in mobile phone use (hours per month), P_{ME} equals the price of using mobile phones in households with electricity ($ per hours), Q_{MN} is the time spent by all members of households without electricity in mobile phone use (hours per month), and P_{MN} is the price of using mobile phones in households without electricity ($ per hours).

Measurement of Benefits

The survey questions necessary for measuring the consumer surplus of using mobile phones involve information on hours of phone use and the price paid for charging mobile phones by households with and without electricity (figure 5-4).

The cost of using mobile phones in grid-connected households is the electricity cost for charging and can be calculated by multiplying the phone watts

Figure 5-4. Questions on mobile phone use

ea1	**Mobile Phone (Grid Households)**	**ea1**	
ea1.1	Number	ea1.1	
ea1.2	Watts per charger	ea1.2	
ea1.3	Total hours of use for all mobile phones per day	ea1.3	
ea1.4	Total hours of charge time for all mobile phones per day	ea1.4	
ea1.5	Electricity tariff	ea1.5	
ea2	**Mobile Phone (Non-Grid Households)**	**ea2**	
ea2.1	Number	ea2.1	
ea2.2	Total hours of use for all mobile phones per day (or last week)	ea2.2	
	Total number of times all phones were charged last week		
ea2.3	Total cost of all charges per day (or per week)	ea2.3	

Source: This study.
Note: In most surveys, these questions can be combined to include both households with and without electricity. For the households without electricity, the time frame of charging phones may be per day or per week, depending on the frequency of charging phones.

by the hours of charging for all phones in the household. The result is then multiplied by the price of electricity to obtain the cost of charging household mobile phones. The price of mobile phone use for households with electricity is calculated by dividing the total hours of phone use by the cost. For households without electricity, the cost of using mobile phones is calculated by the total costs paid for charging the mobile phone, divided by the number of hours of mobile phone use. This provides the information needed to calculate the consumer surplus.

Use of Computers and Fans

The computer is another outlet for acquiring information, enhancing knowledge, and providing entertainment. As a learning tool, the computer is more interactive than either radios or televisions. With the exception of desktop models, most of today's computers are powered by batteries. In developed countries, the use of computers is now prolific, but in areas of developing countries without electricity, computer use is extremely rare. The reason is that batteries, which must be recharged daily, generally provide only 2–8 hours of continuous service, depending on the computer and battery size.

The computer can have a transformative impact on the lives of those living in areas without electricity. The combination of computers and Internet service can make a host of information available, ranging from weather forecasts and market information for crops to news programs and entertainment. The problem in assessing the benefits of computers is that they are still quite rare in areas without electricity. While computers are sometimes run in areas with electricity, unlike radios and televisions there are no parallel situations for running computers in areas without electricity. This makes it impossible to use the consumer surplus approach to evaluate the benefits of computers.

Electric fans, which increase comfort in warm-temperature conditions, are quite common in households with electricity. In warmer-climate countries, electric fans are the second most commonly used appliance. Beyond space conditioning, fans can also drive way mosquitoes and may reduce insect bites. Yet few households without grid electricity have fans because their power demand quickly drains the electricity stored in batteries. This situation makes it difficult to use consumer surplus to compare demand for fans in households with and without electricity

An alternate willingness to pay (WTP) technique that does not use consumer surplus is contingent valuation (CV), which measures WTP by presenting survey respondents future scenarios and asking them how much they would be willing to pay for them. The goal is to understand the future WTP for something that they do not already have. Advocates of this technique have devised clever ways to eliminate speculative bias by presenting survey respondents a random series of scenarios from high to low cost and then asking them to respond to the questions. This method is valid, but it mainly measures the WTP for the capital costs of the appliance. In the case of electric fans, their value in terms of cooling and reducing insect bites far exceeds the purchase price of the appliance. Thus, while it is important for surveys to monitor such appliances as computers and fans, alternate ways of assessment would be necessary to derive an accurate picture of their value.

Conclusion

The use of consumer surplus is a well-established methodology to value the benefits of electricity. The method has been applied to such services as lighting, entertainment, and communications. However, for services that are uncommon in households without electricity (e.g., space conditioning and refrigeration), its application has not been as successful. To uncover some of these benefits, alternate techniques based on regression approaches can be applied, which is the topic of the next chapter.

Chapter 6

Electrification Benefits: Regression-Based Approach

The regression-based approach is probably the most common technique for evaluating the benefits of electricity access. The reason is that regressions can control for factors that may correlate with having electricity. For example, high-income households generally adopt electricity before poorer ones do. The challenge is how to tease out the impacts of electricity compared to income while examining other development outcomes, such as education, health, and other welfare measures. This challenge is further complicated by the fact that part of the increased income may result from electricity access. These and other issues can be dealt with by controlling for other aspects of development in order to discover which development outcomes are attributable to electricity access.

A set of control variables is necessary to tease out the development impact of electricity from the influences of other variables. Such factors as education, income, and assets, among others, must be measured to ensure that the relationship between energy access and other development factors is not spurious. This chapter discusses the techniques that are needed to both measure and analyze the development impact of energy access.

Necessary Control Variables

The regression-based models of impact assessment are based on national, regional, or project surveys. Most such surveys contain essential information for analyzing the impact of energy on various development outcomes. This information is necessary, given that energy is just one input needed for such outcomes as higher income, better education, and improved health. In fact, all development outcomes tend to be highly correlated. Households with higher incomes tend to be healthier and more highly educated. Thus, in order to disentangle the independent impact of energy on any one development outcome, it is necessary to eliminate the impact of the others. This means that, in addition to the intervention variable of grid electricity, other control variables at the household level are expected to have independent effects on the outcomes of interest.

Most household surveys include a standard set of variables to measure possible confounding influences. Of course, there are many ways to measure such control variables (e.g., household composition, level of education, and ownership of land). The use of these variables varies, depending on the intervention and outcomes of interest (box 6-1).

Besides the household control variables, village-level control measures are also included in most outcome equations. These variables, which represent the overall socioeconomic well-being of the community, are expected to exert an influence on the household outcomes (box 6-2).

Box 6-1. Household-level control variables

Common control variables used at the household level to analyze the impact of modern energy on development include the following:

- Age of the individual (YEARS) (only for individual-level regression)
- Age of the individual squared (only for individual-level regression)
- Sex of household head (1 = MALE, 0 = FEMALE)
- Age of household head (YEARS)
- Grade completed by household head (YEARS)
- Number of adult males in the household (age 18 and over)
- Number of adult females in the household (age 18 and over)
- Household land asset (acres)

Source: This study.
Note: Some of these variables are asked of the whole household while others are enumerated for individuals using a household roster.

Box 6-2. Village-level control variables

The village-level control variables necessary for the electricity outcome equations include demographic characteristics, infrastructure services, prices, markets, and schools. The following list of control variables is aggregated from households or collected from village-level questionnaires:

- General demographic characteristics (e.g., village size and population)
- Infrastructure and services in the village (e.g., roads, electricity, and schools)
- Price of energy sources (e.g., kerosene and firewood)
- Tariff and connection cost for grid electricity
- Exogenous shocks (e.g., floods and drought)
- Availability of markets
- Credit availability (e.g., banks or other lending institutions)
- Schools in or distant from community

Source: This study.
Note: Some of these variables are asked of the whole household while others are enumerated for individuals using a household roster.

The main focus of this study is on adopting electricity, along with clean and more efficient methods of cooking (chapter 7). Electricity at both the household and facility level (e.g., schools and health centers) might have an influence on household outcomes. Also, the source of electricity might be important in having an impact on households (box 6-3). For example, households might obtain electricity from such sources as mini-grids or solar home systems (SHSs). In this way, the potential impact of having electricity from grid, mini-grid, and SHSs can be compared to households without any type of electricity.

Of course, the variables listed in box 6-3 include only the main variables necessary for impact evaluation. For example, having electricity may have an impact on nonfarm income. To measure nonfarm income, additional information will be necessary, including duration of the activity, sales, and characteristics of the person receiving the income.

Box 6-3. Energy access variables

Basic energy variables in household or community questionnaires include the following:

- Electricity intervention
- Availability of electricity at home (applies to all types, including grid, mini-grid, and SHSs)
- Availability of electricity for nonfarm activities (applies to income from nonfarm activities only)
- Availability of electricity for farm activities (applies to income from farm activities only)
- Availability of electricity at schools (applies to educational outcomes only)
- Availability of electricity at health facilities (applies to health outcomes only)

Source: This study.
Note: Clean cooking issues are addressed in chapter 7.

Measuring Variables

The variables used in the regression to measure the impact of electricity on development are collected through household and community surveys. Many of these variables can be used directly from the responses of survey questionnaires, while others are calculated from those responses. We rewrite the general equation (3.9) for outcome variables as follows:

$$Y = \alpha X + \beta V + \delta E + \varepsilon, \tag{6.1}$$

where Y represents the outcome, X is a vector of household characteristics (e.g., age and education of household head); V is a vector of community characteristics (e.g., population, area, and infrastructure), E is the electrification variable, parameter δ captures the program impact, and ε is the error term.

This section discusses questions related to household electricity and clean cooking, along with control variables commonly found in impact evaluation studies. The questions related to the energy intervention include whether a household has electricity and the system used. The information necessary for measuring standard household-level control variables is often collected in a household roster section of the survey. The household roster lists all household members and then collects information through questions geared to individual information (e.g., age, sex, and education of all household members) (figure 6-1). It may also contain information on such variables as number of study hours or income; this includes years of education, whether children are attending school, and other factors that allow for the analysis of such characteristics as school attendance at the individual child level according to their age (Annex C).

Figure 6-1. Questions related to mandatory, household-level control variables

Q3.4	Q3.5	Q3.6	Q3.7	Q3.8	Q3.9	Q3.10
Individual ID	Full Name [NAME]	Is [NAME] male or female?	What is the relationship of [NAME] to household head?	How old is [NAME]?	ENUM: Is [NAME] 5 years old or older?	What is the highest grade completed by [NAME]?
	Make a complete list of all individuals who normally live and eat their meals together and live in this household, starting with the head of household. Do not list servants who have a household elsewhere, and guests who are visiting temporarily and have a household elsewhere.	Male…1 Female…2	Head…1 Wife/Spouse…2 Child/Adopted child…3 Grandchild…4 Niece/Nephew…5 Father/Mother…6 Sister/Brother…7 Son/Daughter-in-Law…8 Brother/Sister-in-Law…9 Father/Mother-in-Law…10 Grandfather/Mother…11 Other relative…12 Servant/Servant's relative…13 Other non-relative…14	RECORD "0" IF INFANT BELOW 1 YEAR OLD. Years	Yes…1 No…2 NEXT PERSON	Years
1						
2						
3						
4						

Source: This study.
Note: This question will need revising, depending on the country context, in order to capture grade attainment. A more detailed set of questions is provided in Annex C. The list will be longer than 4 rows. Place as many rows in the form as needed based on information about those residing in households within specific countries.

Household land assets—an important measure of household wealth that generally varies little by year—is a common control variable that should be collected at the household, rather than the individual, level (figure 6-2). For families in agriculture, the entire household is usually involved. This variable is important in rural areas, where most households are involved in farming. Land assets can be substituted for income—a measure more closely related to electricity use—as an indicator of wealth.

Figure 6-2. Questions to capture household land assets

Q3.11	Q3.12	Q3.13	Q3.14
Land ID	**Type of land**	**Area (acres)**	**Value ($)**
1	Homestead land		
2	Total agricultural land (including leased out, rented, and mortgaged areas)		
3	Total non-agricultural land (including ponds, orchards, etc.)		
4	Other land assets		

Once these questions are answered, the household's total land assets is calculated as H_{LAND} equals ΣQ3.13, while the value of all household land assets is given by H_{LANDV} equals ΣQ3.14, where Σ denotes the aggregate for all assets in the household. Either the quantity (acres) or value ($) of the land assets can be used in the outcome equation.[18]

Village-level measures are another set of variables important for regression analysis. Key types of information include village size, local energy prices, distance to the nearest town, and presence of schools (figures 6-3–6-5). Questions on external (exogenous) shocks to the village (e.g., drought) are important because such independent factors might influence many conditions within the village.

[18] Some implementations of the outcome equations use agricultural land instead of total land.

Figure 6-3. Village questions: General questions and fuel price

Q3.15	What is the size of the village? (km^2)
Q3.16	How many households are in the village?
Q3.17	What is the price of agricultural land in the village? ($ per acre)
Q3.18	What is the distance of the village to the nearest city/town? (km)
Q3.19	What is the price of kerosene in the village? ($ per liter)
Q3.20	What is the price of LPG in the village? ($ per kg)
Q3.21	What is the price of charcoal in the village? ($ per kg)
Q3.22	(For villages with electricity) What is the average connection cost that a household pays to get electricity? ($)
Q3.23	What is average tariff of electricity? ($ per kWh)

Source: This study.
Note: Alternate ways of asking these questions are provided in Annexes A–C.

Figure 6-4. Village questions: Infrastructure and availability of services

Q3.24	**Q3.25**	**Q3.26**	**Q3.27**
Infrastructure/ Service ID	Name of the Infrastructure/Service	Does village have it? Yes…1 No…0	If village does not have it, what is the distance from village? (km)
1	Paved roads		
2	Electricity		
3	Primary schools		
4	Secondary schools		
5	Commercial banks		
6	MFIs		
7	NGOs		
8	Hospitals or health care centers		
9	Market		
10	Safety net programs		

Source: This study.
Note: Alternate ways of asking these questions are provided in Annexes A–C.

Figure 6-5. Exogenous village shocks

B28	B29	B30
Shock ID	Name of shock/disaster	Has it occurred in last 12 months? Yes…1 No…0
1	Drought/dry spell	
2	Floods	
3	Unusually high level of crop pests and diseases	
4	Unusually high level of livestock diseases	
5	Unusually high level of human disease/epidemic	
6	Unusually high prices of food	

Source: This study.
Note: Alternate ways of asking these questions are provided in Annexes A–C.

Use of Refrigerator

Refrigeration can allow for better food preservation and improved quality of life. Household members that have refrigerators might have fewer incidences of food spoilage and stomach ailments. Because refrigerated food can be preserved for longer periods, fewer trips are needed to purchase groceries. A study in Argentina found that increased electricity coverage led to increased acquisition of refrigerators (Gonzalez-Eiras and Rossi 2007). However, refrigerators are not commonly the first items purchased when a community receives electricity (World Bank 2002b; 2008).

Quantitative Technique

The main variables for quantifying the benefits of using refrigerators include better preservation, reduction in health problems, and less time spent purchasing food. These benefits can be expressed in terms of following outcomes:

- Value of spoiled food discarded in last month ($),
- Treatment cost for stomach problems in last month ($), and
- Time spent in food purchase in last week (hours).

The specific equations for the three outcomes can be written as follows:

$$V_{FD\_ROT} = \alpha X + \beta V + \delta_{HELEC} + \chi_1(H_{ELEC} * H_{REFRIG}) + \varepsilon, \tag{6.2}$$

$$V_{TR\_COST} = \alpha X + \beta V + \delta_{HELEC} + \chi_2(H_{ELEC} * H_{REFRIG}) + \varepsilon, \text{ and} \tag{6.3}$$

$$T_{FD\_PRCH} = \alpha X + \beta V + \delta H_{ELEC} + \chi_3(H_{ELEC} * H_{REFRIG}) + \varepsilon, \tag{6.4}$$

where X is the set of mandatory household variables (e.g., age and education of household head) (box 6-1); V is the set of mandatory community variables (e.g., village size and population or infrastructure and services) (box 6-2); H_{ELEC} is the household electrification variable; and H_{REFRIG} is the refrigerator ownership variable (the value equals 1 if household has one and 0 otherwise).

The parameter δ captures electrification's own effects, while the χs capture the additional impacts of refrigerator ownership. The interaction term of refrigerator ownership and electrification variable is interpreted as "refrigerator ownership, given that the household has electricity." In this way, the impact of electrification (own effect) can be distinguished from refrigerator ownership (interaction effect).

Measuring Variables

The X and V variables are obtained by asking direct questions on food preservation and illnesses (figure 6-6).

Figure 6-6. Questions on refrigeration for regression-based approach (all households)

Q5.1	Does the household have a refrigerator? (1 = Yes, 0 = No)
Q5.2	Does your household face the problem of food getting rotten? (1 = Yes, 0 = No)
Q5.3	If yes, what was the estimated value of food rotten during last month? ($)
Q5.4	Did any member suffer from stomach problems during last 30 days? (1 = Yes, 0 = No)
Q5.5	If so, what was the cost to treat stomach problems during last 30 days? ($)
Q5.6	How many times did household members go to grocery to buy food in last 7 days?
Q5.7	What was the total time spent by all members to buy food in last 7 days? (hours)

Source: This study.
Note: The food questions are asked of all households; not just those with electricity.

Information from these questions can be used to form the variables necessary for the regression equations. The variables possible from figure 6-7 above are as follows: H_{REFRIG} = Q5.1, V_{FD_ROT} = Q5.3, V_{TR_COST} = Q5.5, and T_{FD_PRCH} = Q5.7. The total benefits of having a refrigerator are thus given as follows:

$$V_{REF\_TOT} = V_{FD\_ROT} + V_{TR\_COST} + V_{FD\_PRCH}. \tag{6.5}$$

As seen above, the time spent in food purchase ($T_{FD\_PRCH,}$ which has a unit of hours per week) can be converted into monetary terms by first multiplying it by 4.3 to obtain the monthly hours, then dividing by 8 to obtain the number of man-days, and finally, by multiplying by prevailing wage;[19] that is,

$$V_{FD\_PRCH} = (T_{FD\_PRCH} *4.3/8)*W,$$

where W is the prevailing wage and V_{FD_PRCH} is the monetary term equivalent to time spent on food purchases.[20] Summing up, the value of avoided food spoilage, treatment cost for stomach problems, and value of time saved on food purchases will provide the total value of adopting a refrigerator.

Kerosene Consumption

An immediate effect for households adopting electricity is a reduction in kerosene consumption. As indicated, a primary motivation for households to adopt electricity is better lighting. This means that electric lamps—one of the first appliances households adopt after receiving electricity—replace the dim, flickering illumination provided by kerosene lamps or candles. As a result, indoor smoke emitted from the polluting kerosene lamps is reduced within the household. This section estimates the direct cost savings of reduced kerosene consumption resulting from electrification, using the regression-based approach.

[19] Monthly measure is derived by multiplying weekly measure by 4.3, not by 4 as conventional wisdom suggests; the reason is that multiplying by 4.3 gives a more accurate measure of the average number of days in a month, which is 30.4.

[20] While community wage is used in this study to measure the value of time, per capita income per day may be preferred since it more accurately reflects household earning potential. This is also because, in areas where unemployment or underemployment is common, applying the prevailing wage may overestimate the value of time.

Quantitative Technique

The effects of electrification on kerosene consumption are estimated using the following equations:

$$V_{KERO} = \alpha X + \beta V + \delta_V H_{ELEC} + \varepsilon, \text{ and} \tag{6.6}$$

$$Q_{KERO} = \alpha X + \beta V + \delta_Q H_{ELEC} + \varepsilon, \tag{6.7}$$

where X is the set of mandatory household variables (e.g., age and education of household head) (box 6-1); V is the set mandatory of community variables (e.g., population, size of village, and infrastructure) (box 6-2); V_{KERO} is the monthly household expenditure on kerosene ($); Q_{KERO} is the monthly consumption of kerosene (liters); parameter δ_V is the effect of electrification on change in kerosene expenditure; and parameter δ_Q is the effect of electrification on change in kerosene consumption.

With these estimates, it is possible to assess the amount of kerosene reduction caused by the adoption of electricity. Households without electricity typically use 4 liters of kerosene per month for lighting. After adopting electricity, this figure can drop to less than one liter a month, depending on local reliability of the electricity supply. Typically, households keep kerosene lamps as a backup lighting source, reverting to their use during power outages. Of course, kerosene might also have household uses beyond lighting, including cooking. With better lighting, households may be able to reduce food processing time during evening hours. With more efficient food-preparation patterns, households may also reduce the amount of kerosene used for cooking.

Measuring Variables

Regardless of kerosene's household use, total consumption is often used for its measurement because of the difficulty survey respondents have in specifying the exact amounts used for cooking, lighting, and heating. If it is necessary to break down end uses, this can be accomplished by asking more questions (Annexes A–C). Here, we focus only on total kerosene use in the households (figure 6-7).

Figure 6-7. Questions on kerosene consumption

Q5.8	How much kerosene did your household consume in last 30 days? (liters)
Q5.9	How much did your household spend on kerosene that was consumed during last 30 days? ($)

The necessary outcome variables can be calculated as follows: Q_{KERO} = Q5.8, and V_{KERO} = Q5.9.

It is important to measure household use of kerosene because the smoke from kerosene wick lamps contains high amounts of carbon and carbon dioxide, which have been linked to health risks. Recent studies show that inhaling the fumes of kerosene lamps over extended periods of time can lead to serious respiratory and other illnesses.

Income, Employment, Expenditure, and Poverty

Household income can increase in a number of ways as a result of electrification. First, households with income-generating activities can extend those activities to evening hours because of the availability of electric lighting. This, in turn, can result in more revenue for the family. For households involved in activities that require motive power, electric machines and tools can increase productivity, in turn, leading to increased income. Television and radios might also facilitate access to farming and business knowledge and information, which can result in better practices with the potential for increasing family earnings.

The relationship between adopting electricity and increasing income or expenditures has been the topic of quite a large amount of research. One national cross-sectional study of rural areas in India compares households with and without electricity, controlling for many other factors. This study finds that grid electrification leads to income growth of 39 percent (Khandker et al. 2014). Another study using a national rural energy survey in Bangladesh has found that income increases 21 percent as a result of grid electrification (Khandker, Barnes, and Samad 2012). Yet another study in Bhutan revealed a 60–70 percent increase in nonfarm income due to electrification, but the research also found no impact on farm income (Kumar and Rauniyar 2011). A study in Nicaragua found that electrification increased women's employment by 23 percent (Grogan and Sadanand 2012).

Only a few longitudinal studies have been completed on the relationship between rural electrification and household income. One study in Vietnam found that for households with electricity, incomes grew over 20 percent on average compared to households that did not adopt electricity (Khandker, Barnes, and Samad 2013). Another study in Brazil examined the labor productivity of households that originally were not in the plans of the power company to receive service due to excessive grid-connection costs. These households had broad increases in labor productivity (Lipscomb, Mobarak, and Barham 2013); these benefits would have been lost if the original power company plan had been followed.

Female employment also seems to increase after a community gains access to electricity. A study on the effect of an electrification rollout campaign in South Africa between 1996 and 2001 found that female employment increased by up to 9.5 percent due to the adoption of electricity (Dinkelman 2011). Specifically, the study found that household electrification saves labor in home production, which, in turn, allows women to engage in the labor market.

Quantitative Technique

The outcome equations for employment (hours per month), income ($ per month), expenditure ($ per month), and poverty can be written as follows:

$$EMP = \alpha X + \beta V + \gamma_H^{EMP} H_{ELEC} + \gamma_{NF}^{EMP} N_{ELEC} + \gamma_F^{EMP} F_{ELEC} + \varepsilon, \tag{6.8}$$

$$INC = \alpha X + \beta V + \gamma_H^{INC} H_{ELEC} + \gamma_{NF}^{INC} N_{ELEC} + \gamma_F^{INC} F_{ELEC} + \varepsilon, \tag{6.9}$$

$$EXP = \alpha X + \beta V + \gamma_H^{EXP} H_{ELEC} + \gamma_{NF}^{EXP} N_{ELEC} + \gamma_F^{EXP} F_{ELEC} + \varepsilon, \text{ and} \tag{6.10}$$

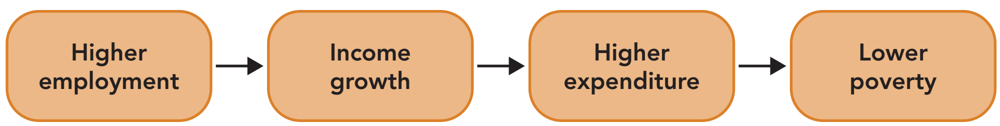
$$POV = \alpha X + \beta V + \gamma_H^{POV} H_{ELEC} + \gamma_{NF}^{POV} N_{ELEC} + \gamma_F^{POV} F_{ELEC} + \varepsilon, \tag{6.11}$$

where X is the set of mandatory household variables (e.g., age and education of household head) (box 6-1); V is the set mandatory of community variables (e.g., population, size of village, and infrastructure) (box 6-2); and H_{ELEC}, N_{ELEC}, and F_{ELEC} represent electrification of household, nonfarm activity, and farm activity, respectively.

These equations highlight the fact that electrification benefits at the household level can accrue not only because of household electrification, but also from electrification of income-generation activities. Nonfarm enterprises and rural farm activities (perhaps through irrigation pumping) can also have an impact on household income.[21] The parameters in the equation capture the effects of electrification at both the household and non-household levels. For example, γ_H^{EMP}, γ_{NF}^{EMP}, and γ_F^{EMP} are the effects on household employment by electrification at the household, industry, and farm levels, respectively.

Because household income, employment, expenditure, and poverty are interrelated, the benefits estimated by equations (6.8)–(6.11) overlap. Obviously, one of the major channels for income growth is higher employment. Such higher income leads to increases in household expenditure. Finally, higher expenditure has the effect of lowering poverty (figure 6-8).

Figure 6-8. Interrelationship among employment, income, expenditure, and poverty



Source: This study.

For simplicity, this section focuses on household income. The other measures of lowering poverty, increased employment and higher expenditures, are correlated with income. With the estimation of the income equation (6.9), the benefits of electricity for household, enterprises, and farm activities will be captured. The equation for aggregate effects of electrification on income can be written as follows: [22]

$$V_{INC} = \gamma_H^{INC} + \gamma_{NF}^{INC} + \gamma_F^{INC}. \tag{6.12}$$

One should note that household income information is often either not collected or unreliable. Survey respondents are often hesitant to provide total strangers their income. As a result, a well-proven proxy for income is household expenditure. The aggregate benefits of electrification on household expenditure can be estimated by equation (6.10), as follows:

[21] The effects of electrification on industries and farm activities are discussed in detail in the following sections.

[22] This is not exactly the direct algebraic sum of the three components, but a weighted sum of the three parameters after the regression is estimated.

$$V_{EXP} = \gamma_H^{EXP} + \gamma_{NF}^{EXP} + \gamma_F^{EXP}. \tag{6.13}$$

In the regressions, expenditures are often expressed in per capita terms. In such cases, the household-level benefits attributed to electricity access or any other intervention would be multiplied by the household size.

Measuring Variables

The X and V variables for equations (6.9) and (6.10) are obtained from questions on income, food expenditure, and recurring and non-recurring nonfood expenditure (figures 6-9–6-12). Measuring income or expenditure is not a simple task. Since household income may come from a wide range of sources,

Figure 6-9. Simplified questions to collect household income

	PLEASE PROVIDE HOUSEHOLD INCOME FROM FOLLOWING SOURCES IN LAST 12 MONTHS
Q5.10	All agricultural activities (crops, fruits, vegetables, plants, etc.) net of all costs (seeds, fertilizer, pesticide, irrigation, labor, etc.) ($)
Q5.11	All livestock, poultry, and fishery activities net of all costs (fodder, grazing, etc.) ($)
Q5.12	Products and services from nonfarm activities (manufacturing, processing trading, retailing, shops, restaurants, etc.) ($)
Q5.13	Renting/operating transport vehicles (cars, trucks, pick-ups, motorcycles, bicycles, etc.) net of all costs (maintenance, repair, driver's salary, etc.) ($)
Q5.14	Self-employed profession (physician, nurse, lawyer, tutor, etc.) and contracting jobs (plumber electrician, mason, etc.) ($)
Q5.15	Wage employment in farm sector ($)
Q5.16	Wage and salaried employment in nonfarm sector ($)
Q5.17	Renting out of land, building structures (houses, shops, warehouses, shades, etc.), agricultural and non-agricultural equipment net of all costs (maintenance, repair, tax, etc.) ($)
Q5.18	Interest and profits from investments (stocks, bonds, shares, insurance schemes, etc.) and savings scheme ($)
Q5.19	Remittances ($)
Q.5.20	Pension, retirement funds, and royalty ($)
Q5.21	Government or NGO safety net programs, charities, and donations ($)
Q.5.22	Other sources not yet covered ($)

Source: The World Bank's *Living Standard Measurement Study (LSMS)* (http://go.worldbank.org/IPLXWMCNJ0).
Note: The LSMS surveys provide a good source of detailed income and expenditure questions; for demonstration, we report simplified questions on income and expenditure here and in figures 6-10–6-12.

Figure 6-10. Simplified questions to collect household food expenditure

	PLEASE PROVIDE THE VALUE OF FOOD CONSUMED IN LAST 7 DAYS
Q5.23	Food consumed from purchase ($)
Q5.24	Food consumed from own production ($)
Q5.25	Food consumed from gift, collection, or obtained in other ways ($)

Source: The World Bank's *Living Standard Measurement Study (LSMS)* (http://go.worldbank.org/IPLXWMCNJ0).

Figure 6-11. Questions to collect recurring household nonfood expenditure

	PLEASE PROVIDE THE VALUE OF THE FOLLOWING RECURRING NONFOOD EXPENDITURE IN LAST 30 DAYS
Q5.26	House/land rent ($)
Q5.27	Utility (electricity, water, land phone, mobile phone bill and recharge, dish, cable, etc.) ($)
Q5.28	Non-electricity energy consumption (kerosene, candles, dry-cell, firewood or other biomass) ($)
Q5.29	Cosmetics, toiletries, soap, and household cleaning products ($)
Q5.30	School expense for children ($)
Q5.31	Wages of domestic workers ($)
Q5.32	Entertainment ($)
Q5.33	Other monthly expenditures ($)

Source: The World Bank's *Living Standard Measurement Study (LSMS)* (http://go.worldbank.org/IPLXWMCNJ0).

Figure 6-12. Questions to collect non-recurring household nonfood expenditure

	PLEASE PROVIDE THE VALUE OF THE FOLLOWING NON-RECURRING NONFOOD EXPENDITURE IN LAST 12 MONTHS
Q5.34	Clothing, shoes, and accessories ($)
Q5.35	Purchase, development, and repair of house, land, shops, buildings, etc. ($)
Q5.36	Purchase and repair of household goods, furniture, and appliances ($)
Q5.37	Purchase and repair of transport vehicles (motorcycles, cars, carts, boats, etc.) and agricultural and non-agricultural equipment ($)
Q5.38	Medical expenses ($)
Q5.39	Social and religious occasions, marriages, and funerals ($)
Q5.40	Remittances sent to family members and relatives ($)
Q5.41	Losses due to fines, theft, robbery, accidents, natural disasters, etc. ($)
Q5.42	Other major expenses. ($)

Source: The World Bank's *Living Standard Measurement Study (LSMS)* (http://go.worldbank.org/IPLXWMCNJ0).

detailed questions specific to these sources must be asked separately. Similarly, levels of household expenditure must be collected by asking questions about all food and nonfood items that the household consumes.

Nearly every survey contains various forms of these questions (Annexes A–C). The figures above demonstrate the types of information necessary to construct income and expenditure measures. Depending on the importance of income for the analysis, the number of questions can be expanded on or reduced. Obviously, income is quite an important variable for assessing the impact of energy access on development; for this reason, thought should be given before omitting important components for measuring either income or expenditure.

Income-Generating Activities

Households sometimes engage in income-generating activities. Home-based family businesses can take advantage of electricity to improve household income. For example, because of improved lighting from electricity, such home-based businesses as handicrafts or even small retail shops can operate longer during evening hours. Income-generating activities may also be located outside the household, including enterprises that use electricity to power machinery and tools, as well as for lighting.[23] Although electric machines and tools can be expensive, they result in time savings for doing certain work tasks owing to their efficiency. Jobs can be done more quickly at less cost, so the volume of productive activities can be increased. This extra time can be used for alternate productive or socially valuable activities. For example, farm households may use electricity to power irrigation pumps, which, in turn, can raise crop productivity. This section assesses the income benefits of farm and nonfarm income-generating activities that derive from electricity.

One should note that this analysis differs from an investigation of the impact of electricity on all household income. This section focuses on the benefits of electricity for enterprises in the community. Of course, enterprise profits are a part of total household income. Therefore, the analysis centers on the more direct impacts of electricity resulting from enterprise development.

[23] This is not to imply that home-based activities do not use high-powered electric machinery; given the scale of home-based activities, lighting is the main use of electricity.

Many studies have found that electricity has an impact on household income and productivity. One of the first studies to review the literature on increases in rural production caused by rural electrification was carried out in India, Colombia, and Indonesia (Barnes 2014). This study found significant increases in farm production in India, where irrigation plays a key role in agriculture. In the 1960s, the government had a significant program for promoting electric pumpsets. A later study in rural India found that, due to electric pumpsets, the productivity of small-scale farmers increased by about 50 percent (Monari and Mostefai 2001). For medium- and large-scale farmers, the increase was smaller, but still significant, at 15 percent.

It has long been argued that much development potential may be lost by failing to extend electricity to rural areas. Mellor (1976) argued for an employment-oriented, decentralized growth strategy for developing nations, premised on large investments in rural infrastructure, including electricity. The development of large-scale urban factories without comparable investments in rural areas might result in uneven development patterns typified by the so-called dual economies observed in many Third World countries, where the rich get richer and the poor get poorer. According to Mellor (1976), direct investment in public services that facilitate small-scale industrial and commercial growth should take precedence over the construction of large-scale factories.

In Indonesia, most productivity increases did not come from agriculture; rather, they resulted from new business activity (Barnes 2014). At the time, new businesses were increasingly using electricity, but it was difficult for owners to obtain loans for new equipment; thus, it sometimes took a long time to replace diesel-driven machinery. A study in the Philippines found that, due to surface irrigation practices, the availability of electricity did not lead to increases in irrigation and gains in agricultural productivity (World Bank 2002a). Like the Indonesia case, however, it did lead to greater small business production. Therefore, studies on the impact of electricity on income-producing activities should not ignore the complementary conditions.

Later studies have confirmed the findings of the early ones on the relationship between electricity and productive activities. A macro study conducted in rural India found a relationship between the expansion of electricity and manufacturing output during 1965–1984 (Rud 2012). For every one standard deviation in the electricity connections, manufacturing output improved by 14.7

percent. However, not all studies find a connection between rural productivity and electricity. One study in Benin, for example, found that, while the adoption of electricity encourages people to undertake new production activities, there is no evidence of significantly higher profitability of firms (Peters, Vance, and Harsdorff 2011). It should be cautioned, however, that such studies often examine profits over a short term, during which the capital costs of new machinery can be quite significant.

Quantitative Technique

For rural areas, the two main income categories involve farm and nonfarm activities. For the purposes of this analysis, these two activities are discussed separately. Just as the regression framework was used to estimate the electrification impacts on household income, a similar regression technique can be used to estimate the impacts of firm or farm electrification on profits.

The nonfarm category of activities comprises manufacturing, small-scale production, handicrafts, cottage industries, small businesses, retail stores, service activities, and many others. The techniques involved in measuring the increases in income due to electricity access at the firm level can be captured by the following equation:

$$INC_{NF} = \alpha X + \beta V + \gamma_{NF}^{INC} N_{ELEC} + \varepsilon \, , \tag{6.14}$$

where X is a set of various enterprise characteristics that are expected to influence enterprise profits (see figure 6-16)*;* V is the set of mandatory community variables (e.g., population, village size, and infrastructure (box 6-2); INC_{NF} is the income (profit) from the nonfarm enterprise activity ($ per month); N_{ELEC} is the enterprise-level electrification (a 1/0 variable); and the parameter γ_{NF}^{INC} captures the effects of enterprise electrification on enterprise profit.

Nonfarm activities may be home-based or stand-alone. Most home-based activities, which are usually small in scale, use the household's electricity connection. By contrast, stand-alone activities are generally larger in scale and have a separate electricity connection specifically for the business. The impact of electricity on farm income can be the result of increases in the use of electric pumps, an increase in information related to farm activities, and the use of other types of electric machinery (e.g., threshers or fodder choppers). This study focuses on the methods for assessing electricity's impact on irrigation. In this case, electricity's use in agriculture mainly involves operating electricity-powered irrigation pumps. The hypothesis is that farmers who use electric pumps for irrigation benefit more than those who use manual irrigation or diesel pumps. For the same cost of irrigation, electric pumps are expected to be more efficient in that they pump more water than manual irrigation. The increased output of electric pumps allows farmers to irrigate more land area, as well as the same land area, during multiple seasons. As a result, farmers using electric pumps can expect a higher crop productivity than that of farmers who do not use electric pumps for crop production.

Using a farmer-level outcome equation, an assessment can be made of the gain in crop productivity due to electricity-powered irrigation. The profit equation for crop production activities can be written as follows:

$$INC_F = \alpha X + \beta V + \gamma_F^{INC} N_{ELEC} + \varepsilon, \tag{6.15}$$

where X is a set of various pump characteristics that are expected to influence crop production profits (figure 6-18); V is the set of mandatory community variables (e.g., population, village size, and infrastructure (box 6-2); INC_F is the income (profit) from crop production activities ($ per month); F_{ELEC} is the use of electric pumps in crop production (a 1/0 variable); and γ_F^{INC} captures the effects of using electric pumps on farm profit.

Measuring Variables

Like total income, income from enterprise activities requires a set of questions on revenues and operating expenditures for such activities (figures 6-13–6-15).

For agricultural activities, the pared-down standard X and V variables in equation (6.15) are obtained from questions on income and farming practices (figures 6-16–6-17). Like nonfarm income, the farm income category requires detailed questions for calculating income. Additional control variables are also needed for conducting the analysis of electricity's impact for farm income. These are the basic questions.[24] The point is that information must be collected on the total value of farm production from which the expenses must be subtracted in order to obtain farm productivity.

[24] Additional types can be found in Annex C.

Figure 6-13. Income from home business

SOCIOECONOMIC (SE)			
SE1	Do you have a business at home? [0] No. If no, go to next section. [1] Yes	SE1	
SE2	If yes, what is the type of business? [1] Hairdresser/barber [2] Tailor/dressmaker [3] Laundry [4] Carpentry . . . [-1] No response [-8] Not applicable	SE2	
SE3	What is the number of hours worked per week in your home business?	SE3	
SE4	What is the revenue of the home business per month?	SE4	
SE5	What are the expenses of the home business per month?	SE5	

Source: This study based on a variety of surveys.

Figure 6-14. Questions to collect income from separate business

	PLEASE PROVIDE THE FOLLOWING INFORMATION ABOUT HOUSEHOLD INCOME FROM NONFARM ACTIVITIES FOR LAST 12 MONTHS
Q5.43	Revenue from products and services ($)
Q5.44	Cost of raw materials and supplies ($)
Q5.45	Payment for utilities (electricity, water, gas, phone, etc.) ($)
Q5.46	Cost of hired labor ($)
Q5.47	Rental cost of land, buildings, and equipment ($)
Q5.48	Interest on loans, tax, legal fees, registration fees, insurance, etc. ($)
Q5.49	Other expenditures ($)

Source: This study based on a variety of surveys.

Figure 6-15. Questions to collect control variables (X) for nonfarm income-generating activities

Q5.50	What is the gender of the main operator the activity? (1 = Male, 0 = Female)
Q5.51	What is the age of the main operator the activity? (Years)
Q5.52	What is the education of the main operator the activity? (Years)
Q5.53	Where is the activity located? 1 = Within Household Premise, 2 = Outside Household Premise Roadside, 3 = Outside Household Premise Away From Road, 4 = Within A Market, 5 = Other Purpose (Specify ___________________)
Q5.54	Is the activity formally registered? (1 = YES, 0 = NO)
Q5.55	How many years has the activity been in operation? (Years)
Q5.56	How many months per year is the activity operated? (Months)
Q5.57	What type of activity is it? 1 = Manufacturing/Processing, 2 = Retail shop/Grocery, 3 = Trading, 4 = Service, 5 = Restaurant/Food shop, 6 = Repair/Maintenance shop, 7 = Others (Specify ___________________)
Q5.58	What is the main source of fixed capital? 1 = Own capital, 2 = Commercial bank, 3 = Microcredit, 4 = Informal moneylenders, 5 = Friends/Relatives, 6 = Others (Specify ___________________)
Q5.59	What is the main source of working capital? 1 = Own capital, 2 = Commercial bank, 3 = Microcredit, 4 = Informal moneylenders, 5 = Friends/Relatives, 6 = Others (Specify ___________________)
Q5.60	What is the value of fixed assets of the enterprise (land, building structure, machinery, furniture, etc.)?
Q5.61	Does the enterprise have electricity? (1 = YES, 0 = NO)
Q5.62	If YES, what is the source electricity? (1 = Grid, 2 = Mini-grid, 3 = Solar, 4 = Generator, 5 = Others (Specify ___________)
Q5.63	Does the enterprise use diesel? (1 = YES, 0 = NO)
Q5.64	Does the enterprise use kerosene? (1 = YES, 0 = NO)
Q5.65	Does the enterprise use LPG? (1 = YES, 0 = NO)
Q5.66	Does the enterprise use charcoal or coal? (1 = YES, 0 = NO)
Q5.67	Does the enterprise use firewood? (1 = YES, 0 = NO)

Source: This study based on a variety of surveys.

Figure 6-16. Questions to collect income from agricultural activities

	PLEASE PROVIDE THE FOLLOWING INFORMATION ABOUT HOUSEHOLD INCOME FROM CROP PRODUCTION IN LAST 12 MONTHS
Q5.68	What was the value of all crops that your household produced (including those consumed, stocked, given as wage, fed to animals, byproducts, etc.)? ($)
Q5.69	How much did your household spend on seeds and fertilizer? ($)
Q5.70	How much did your household spend on pesticides? ($)
Q5.71	How much did your household spend on tilling animal, tractors, threshers or other equipment (excluding irrigation pumps)? ($)
Q5.72	How much did your household spend on hired labor for these agricultural activities? ($)
Q5.73	What type of irrigation was used for crop production? (1 = MANUAL, 2 = DIESEL, 3 = ELECTRIC)
Q5.74	If used MANUAL irrigation, how much was the cost for water purchased? ($)
Q5.75	If used DIESEL irrigation, how much was paid for diesel? ($)
Q5.76	If used ELECTRIC irrigation, how much was paid for electricity? ($)
Q5.77	If used DIESEL or ELECTRIC irrigation, how much was paid for repair, maintenance, lubricant, etc. for the pump? ($)
Q5.78	If other expenditure was incurred in crop cultivation, how much was that? ($)

Source: This study based on a variety of surveys.

Figure 6-17. Questions on control variables for farm income-generating activities

Q5.79	What is the total land under cultivation for the household? (acres)
Q5.80	How much of the total land was used for one season only? (acres)
Q5.81	How much of the total land was used for two seasons? (acres)
Q5.82	(If applicable) How much of the total land was used for three seasons? (acres)
For Owners of Diesel or Electric Irrigation Pumps	
Q5.83	What is the capacity of the pump? (horse power)
Q5.84	How old is this pump? (months)
Q5.85	How much did you pay for this pump? ($)
Q5.86	How long have you been using diesel [or electric] pump? (years)
Q5.87	How many days in total did you use this pump for irrigation in the last year? (days)
Q5.88	How much land was irrigated last year with this pump in the first season? (acres)
Q5.89	How much land was irrigated last year with this pump in the second season? (acres)
Q5.90	How much land was irrigated last year with this pump in the third season? (acres)

Source: This study based on a variety of surveys.

Calculating the farm- and firm-level income is not an easy task. Some of the variables involve different time periods. Also, many farms have two or three cropping seasons. For the firm level, many expenses involve capital costs while others are for operational purposes. Capital goods last for many years, and the costs must be annualized over a period of years. Even though it is difficult, the income from both farm and nonfarm activities can be a significant monetary benefit of electricity. Therefore, omitting such income can lead to significant underestimation of the overall benefits of electricity.

An example of the impact of electricity on income, expenditure, and poverty has been conducted for Bangladesh (box 6-4). This study shows that the

Box 6-4. Electrification impacts on economic outcomes in Bangladesh

Using a regression technique with cross-sectional survey data from rural Bangladesh, grid electricity is found to impact household economic outcomes (e.g., income, expenditure, and poverty). The data were collected by the Rural Electrification Board (REB) in 2005 to investigate the welfare impacts of electrification, particularly of the World Bank–funded Rural Electrification and Renewable Energy Development (RERED) program. The survey collected information on household income from various sources and expenditures.

Table B6-4.1 Household electrification impacts on economic outcomes in rural Bangladesh

N = 20,900

Outcome variable	Effects of household access to electricity
Log per capita total income (Tk/year)	0.212** (0.034)
Log per capita expenditure (Tk/year)	0.113* (0.022)
Moderate poverty	−0.133** (0.030)

Source: Khandker, Barnes, and Samad 2012.
Note: Figures in parentheses are standard errors. * and ** refer to significance levels of 10 percent and 5 percent or better, respectively. Controls include household demographic characteristics (e.g., age and sex of household head, maximum education of household males and females, land assets, access to tubewell, and household dwelling is brick-built) and village prices of alternate fuel.

Table B6-4.1 shows that electrification improves household income and expenditure and lowers poverty. More specifically, household per capita income increases by 21.2 percent and expenditure rises by 11.3 percent due to electrification. In addition, expenditure growth results in 13.3 percentage points of poverty reduction.

impact of electricity is more than 20 percent for income and over 10 percent for expenditure. This is a direct measure that shows electricity has a significant impact on human welfare. Also, the findings from the income results are somewhat consistent with the consumer surplus approach. These two measures differ a bit, but the assumptions on which each calculation is based are quite different. Overall, it is better to measure the impact of electricity for development more directly using the regression approach; however, the consumer surplus approach is also a good approximation of the benefits of electricity for development.

Education

Electricity has been found to extend the study hours of school-going children and lessen the likelihood that children will drop out of school. Once households adopt electricity they have access to a higher quality of lighting, giving students the opportunity to study longer hours during the evening. Being better prepared for class leads to an increase in school enrollment and staying in school longer. In addition, once a community has electricity, schools can have a higher quality of lighting and purchase teaching aids for classroom use. Having electricity at school can provide a comfortable learning environment and allow for such services as computers and the Internet, in turn, offering better access to knowledge and information. Moreover, schools with electricity are more likely to attract qualified teachers. These combined factors contribute to better learning and a higher grade attainment for students. In the long run, more years of education can make a difference in the future income of household members.

In the education literature, the role of energy is rarely recognized as promoting higher school attendance. By contrast, the energy literature has a long history of observing electricity's important role in improving educational achievements (Saunders et. al. 1975; Madigan, Herrin, and Mulcahy 1976; Barnes 1988; Khandker 1996; World Bank 2002a; Tanguy 2012). Most of these studies have mainly reported correlations between rural electrification and educational improvements. More recently, advanced techniques are confirming that electricity is a significant cause of improvements in higher school attendance (Khandker, Barnes, and Samad 2012).

Studies in various countries have found that electricity is related to higher educational attainment. In Bhutan, for example, electricity led to an increased grade attainment by up to 0.74 grades (Kumar and Rauniyar 2011). In Brazil, a macro study of counties covering the 1960–2000 period found that the increase in electricity was associated with a 22 percent reduction in illiteracy (Lipscomb, Mobarak, and Barham 2012; in addition, the number of people with less than four years of education was reduced by 19 percent. A study in rural Vietnam found that household electrification increased boys' and girls' school enrollment by up to 8.2 percentage points and 9.5 percentage points, respectively (Khandker, Barnes, and Samad 2013). The same study found that electrification increased the respective grade attainment of boys and girls by up to 0.16 grades and 0.08 grades. A study in India found that boys' and girls' school enrollment went up by 6 percent and 7.4 percent as a consequence of electricity (Khandker et al. 2014). In rural Bangladesh, electricity increased boys' and girls' respective grade attainment by 0.23 grades and 0.16 grades.

Quantitative Technique

The benefits of electrification for school-age children, typically ages 5–18, can be measured through three possible outcomes: an increase in study hours, growth in school enrollment, and improvement in the likelihood that children will stay in school. These outcomes can be translated into economic or income gains. Mincer (1974) was responsible for starting an entire research tradition by analyzing the returns to education for adults. Adults in households with electricity generally have a higher level of education than those in households without electricity. Also, children in households with electricity generally will become more highly educated than their parents.

In most countries, the available existing evidence on returns to education can then be used to monetize the benefits of electricity through increasing years of education. The pathways related to electricity involve the movement from gaining access to electricity through staying in school to achieve higher years of education (figure 6-18). This, in turn, results in higher income for the

Figure 6-18. Pathways from electrification to higher income through education

Source: This study.

individual. This process is long term and thus gains are not immediate. However, the returns to education are generally quite significant and, over the long run, can lead to higher income streams.

Since higher grade attainment captures the benefits of study hours and school enrollment, it makes sense to estimate the outcome equation using grade attainment. Electricity can have an impact on grade attainment through electricity access in both households and schools. The outcome equation for grade attainment in terms of both household and school electrification can be written as follows:

$$GRADE = \alpha X + \beta V + \gamma_{H}^{GR} H_{ELEC} + \gamma_{SCH}^{GR} S_{ELEC} + \varepsilon, \tag{6.16}$$

where X is the set of mandatory household variables (e.g., age and education of household head) (box 6-1); V is the set of mandatory community variables (e.g., population, size of village, and infrastructure (box 6-2); H_{ELEC} is household electrification status; S_{ELEC} is school electrification status; and γ_{H}^{GR} and γ_{SCH}^{GR} are the respective effects of household and school electrification on grade attainment.

This equation can be estimated separately for boys and girls ages 5–18 and for other age groups (e.g., primary, middle, and high school). The total impact of electricity on grade attainment is the aggregate benefit due to both households with electricity and schools with electricity. After estimating equation (6.16), the aggregate impact of household electrification and school electrification on grade attainment is given by the following equation:

$$G_{ELEC} = \sum \left(\gamma_{H}^{GR} + \gamma_{SCH}^{GR} \right), \tag{6.17}$$

where Σ implies the household level aggregation of the benefits of electrification on grade attainment for all school-going children. The benefit in grade attainment can be translated into monetary values as follows:

$$V_{EDUC} = G_{ELEC} {}^{*} I_{GR}, \tag{6.18}$$

where V_{EDUC} is the monetary benefits of electrification on grade attainment, and I_{GR} is the increase in monthly household income for one year of increase in grade attainment.

The increase in monthly household income is not estimated directly from the survey, but is a country-specific value that comes from other studies on returns to education. This is the average private monetary return for one additional year of education. It is usually given in lifetime earnings; however, the yearly gains can be calculated based on estimated years in the workforce.

A wide body of literature is available on the possible value of returns to education (Psacharopoulus and Patrinos 2004; Psacharopoulus 1994; Peet, Fink, and Fawzi 2015; Patrinos, Ridao-Cano, and Sakellariou 2006). These studies can be used to determine the country-specific value of I_{GR}.[25] A recent study using 61 nationally representative household surveys from 25 developing countries finds an average return to schooling of 7.6 percent (Peet, Fink, and Fawzi 2015). Another study provides a similar estimate of about 10 percent annual return to education (Psacharopoulus and Patrinos 2004).

Measuring Variables

The mandatory *X* and *V* variables in equation (6.16) include such measures as income, household land assets, and distance from other infrastructure, among others. One additional control variable that has proved important for school attendance is distance from school in terms of both miles and minutes (figure 6-19). The difficulty in getting to and from school is very important for children in the primary grades, but becomes a bit less important for youth in middle and high school. Most communities have a primary school, but middle and high schools may be located in central villages, which have larger populations.

Most educational research focuses on the impact of school characteristics on school attendance. For this reason, it is a good idea to have both school and village characteristics as control variables in measuring school attendance. Some of the possible questions to capture the school characteristics include whether the school is public or private and the number of teachers (figure 6-20). These questions are asked at the school, and the most common respondent would be the principal.

[25] One should note that the studies cited give the return in terms of percentage of income, which must be multiplied by the average income per month to obtain the I_{GR} value.

Figure 6-19. Questions to collect an additional control variable at the household level for outcome equation for grade attainment

Q5.91	What is the travel time for your school-age children (in minutes) for the following types of schools? (codes: time in minutes, no children in that type of school, no response) Primary ______________ Middle ______________ High School __________
Q5.92	What is the travel distance for your school-age children (in minutes) for the following types of schools? (codes: time in miles, no children in that type of school, no response) Primary ______________ Middle ______________ High School __________

Source: This study.

The application of this method for evaluating the impact of electricity on education has been completed in India (box 6-5). Even after controlling for other important variables, electricity clearly has significant impacts for children in rural India. No doubt, the ability to study more in the evening translates into better school performance, which is confirmed by a concomitant increase in school enrollment. The increase in school enrollment could be translated into a monetary benefit by reviewing studies on returns to education for India.

Health

Health outcomes can improve because of electricity as a result of acquiring knowledge, mostly through media access, such as listening to radio and watching TV. While these activities can be done without access to electricity (e.g., by using battery-powered radio or TV), electricity access makes them much cheaper. Another important health benefit of electrification comes through elimination of kerosene-based lighting. Exposure to smoke from kerosene combustion increases the risk of respiratory disease, impaired lung function, tuberculosis, and eye problems, not to mention the risk of burn and injury due to fire (Lam et al. 2012a). In developing countries, kerosene combustion results from use of kerosene (i) for lighting and (ii) as a cooking fuel. By replacing kerosene lamps with electric bulbs, electrification can reduce the exposure to kerosene smoke

Figure 6-20. Questions on school characteristics as part of school questionnaire

Q5.91	How old is the school? (years)
Q5.92	What is the school type? (1 = GOVERNMENT, 2 = PRIVATE, 3 = NGO-RUN, 4 = COMMUNITY-RUN, 5 = OTHER [Specify____________________])
Q5.93	What is the highest level of education available in the school? (1 = NURSERY/KINDERGARTEN, 2 = PRIMARY, 3 = SECONDARY, 4 = POST-SECONDARY)
Q5.94	How many male teachers are in the school?
Q5.95	How many female teachers are in the school?
Q5.97	Is the headmaster (headmistress)/principal male or female? (1 = MALE, 0 = FEMALE)
Q5.98	What is the education level of the headmaster (headmistress)/principal? (1 = MS OR ABOVE, 2 = BS, 3 = SECONDARY DIPLOMA, 4 = OTHER [Specify])
Q5.99	What is the school's average class size?
Q5.100	How many teachers have BS degree or above?
Q5.101	What is the structure of the school construction? (1 = BRICK/CONCRETE BUILDING, 2 = SEMI-CONCRETE BUILDING, 3 = OTHER [Specify________________________])
Q5.102	What is the source of drinking water? (1 = PIPED WATER INSIDE THE FACILITY, 2 = PIPED WATER OUTSIDE THE FACILITY, 3 = TUBEWELL/HAND PUMP, 4 = OTHER [Specify_________________________])
Q5.103	Are there separate toilets for boys and girls? (1 = YES, 0 = NO)
Q5.104	Does the school have electricity? (1 = YES, 0 = NO)
Q5.105	If YES, what is the source electricity? (1 = Grid, 2 = Mini-grid, 3 = Solar, 4 = Generator, 5 = Other [Specify ___________])
Q5.106	If YES, how long has the school had electricity? (years)
Q5.107	If YES, what is the source electricity? (1 = Grid, 2 = Mini-grid, 3 = Solar, 4 = Generator, 5 = Other [Specify ___________])
Q5.108	Does the school have a library? (1 = YES, 0 = NO)
Q5.109	Do the students have access to computers? (1 = YES, 0 = NO)

Box 6-5. Electrification impacts on educational outcomes in India

A regression analysis using the India Human Development Survey (IHDS) data of 2005 shows how electrification can have positive impacts on educational outcomes of school-going children ages 5–18. This survey collected information on children's study hours, school enrollment, and completed schooling years, along with the household's grid connectivity.

Table B6-5.1 Household electrification impacts on educational outcomes in India

N = 23,868 (boys); 22,484 (girls)

Outcome variable (children, ages 5–18)	**Effects of household access to electricity**
Boys' school enrollment	0.060* (3.51)
Girls' school enrollment	0.074* (4.19)
Boys' study time at home (hours/week)	1.359* (5.63)
Girls' study time at home (hours/week)	1.579* (6.35)
Boys' completed schooling years	0.284* (3.34)
Girls' completed schooling years	0.489* (5.17)

Source: Khandker et al. 2014.
Note: Figures in parentheses are t-statistics. * refers to a significance level of 5 percent or better. Controls include household demographic characteristics (e.g., age and sex of household head, maximum education of household males and females, land and nonland assets, and access to tap water and flush toilet) and village characteristics (e.g., population density; distance to district headquarters, paved road, and market; presence of social programs [NGO, food-for-work, government employment, and adult education]; and prices of alternate fuels and consumer goods). Instruments include proportion of village households with electricity and the interactions of electricity with the amount of household agricultural land and the age, sex, and education of household head.

Table B6-5.1 shows that electrification increases boys' and girls' weekly study time by about 1.36 hours and 1.58 hours, respectively. Also, more children from households with electricity are enrolled in school than those from households without electricity. As a result of electrification, girls' enrollment rises by 7.4 percentage points and boys' by 6 percentage points. In the end, these outcomes contribute to better educational performance, which is captured by completed schooling years, as shown in the table. One interesting aspect of these findings is that girls do better than boys due to household electrification.

to a great extent. Many households with electricity adopt cleaner ways of cooking, such as the use of LPG or improved stoves. These combined factors can have an impact on health.

Evaluating the impact of electricity on health benefits is complicated by two main issues. First, most health studies rely on self-reported illnesses, meaning that the respondents must understand when they are sick. But someone with a chronic cough may not be aware that he or she has a health issue. Second, over a short period of time (e.g., one month), it is likely that only a small number of people will become ill. This means that, in a random sample, perhaps only 5–10 percent of respondents will report having a particular symptom and even fewer will indicate that they have a specific disease. The small number of people in the sample with illnesses may not be large enough to make generalizations for the whole population. For this reason, this review of health benefits is confined to questions that might be asked in the questionnaire (figure 6-21).[26]

As mentioned, control for additional variables—including health facilities at the health center level—is necessary. Figure 6-22 shows the questions required to collect those additional control variables.

Figure 6-21. Questions to collect an additional control variable at the individual level for health outcomes

Q5.110	(To all members individually) Did you suffer from any short-term illness during last 30 days? (1 = YES, 0 = NO)
Q5.111	If YES, how many work days were lost due to such illnesses during the last 30 days?
Q5.112	If YES, how much was the cost of treatment for such illnesses? ($)
Q5.113	If YES and you went to a health facility for treatment, how long does it take for you to go there? (minutes)

Note: For short-term morbidity, the options for this question would include cough/cold, common fever, headache, breathing problems, acidity/indigestion, diarrhea, dysentery, abdominal pain, ear/eye problems, skin problems, and vomiting. For accuracy of response, each of these questions would have to be asked individually, followed up by the assessment of days lost and the cost of treatment.

[26] The questions on health recall have been questioned by many researchers, but they are still commonly used in many health surveys. The bigger problem is that illness is not that common, so a fairly large sample size is necessary to capture the impacts of electricity for health.

Figure 6-22. Questions to collect health-facility characteristics

Q5.114	How old is the health facility? (years)
Q5.115	Type of health facility (1 = HOSPITAL, 2 = HEALTH CENTER, 3 = CLINIC, 4 = DISPENSARY, 5 = OTHER [Specify____________________])
Q5.116	How many doctors are in the facility?
Q5.117	How many nurses are in the facility?
Q5.118	How many patients were treated during the last 30 days?
Q5.119	Does this facility have an operation theater? (years) (1 = YES, 0 = NO)
Q5.120	Does the facility have electricity? (1 = YES, 0 = NO)
Q5.121	If YES, what is the source of electricity? (1 = Grid, 2 = Mini-grid, 3 = Solar, 4 = Generator, 5 = Other [Specify____________________])

Few studies on rural electrification have been able to calculate the impact on health. The reasons have involved the infrequency of individuals becoming sick and, of course, whether electricity does or does not have an impact on health. These two problems have vexed researchers because it is fairly obvious that electricity has at least the potential to improve health. But one should keep in mind that many other factors also have an impact on health, including stove type, quality of water used in the household, and local sanitary conditions, among many others. Thus, it has been difficult to tease out the health impact of electricity for households in developing countries.

Conclusion

The equations and survey questions provided in this chapter should point the way forward for developing good methods to evaluate the benefits of energy access in specific countries or regions of the world. It should be understood that the regression methods and questionnaires for examining the impact of energy access on development can take many forms (Annexes A–C). The examples in this chapter provide a framework for examining the outcomes of energy access. However, in order to understand the relationship between energy access and development outcomes, it is necessary to conduct surveys and analyze the results in a way that avoids confusing causes and effects. Those surveys must be based on the specific concerns of policy makers in a given country or context.

Chapter 7

Assessing the Benefits of Clean Cooking: Regression-Based Approach

Open fires and primitive stoves have been used for cooking since the beginning of human history. They have come in various sizes and styles, having been adapted to myriad cultures and food preparation methods. As society has progressed, more sophisticated stove models have been developed. Today's modern kitchens reflect the many types of standardized and specialized cooking devices available, from coffee pots and tea kettles to toasters and gas stoves.

Unfortunately, many people in developing countries still burn biomass energy on primitive stoves to meet their household cooking needs. These open fires are inefficient at converting energy into heat for cooking. Each year the amount of biomass fuel for meeting basic cooking needs can reach up to 2 tons per family. Collecting such a large amount of fuel can translate into spending an hour per day on this task. Furthermore, open fires and primitive cookstoves emit a significant amount of smoke into the kitchen and other parts of the home. This indoor cooking smoke has been associated with a number of diseases, the most serious of which are chronic and acute respiratory illnesses including bronchitis and pneumonia. Moreover, where demand for local biomass energy outstrips the natural regrowth of local resources, environmental problems can result. There is evidence that biomass fuels burned in traditional ways contribute to a build-up of greenhouse gases (GHGs) (Venkataraman et al. 2010). Some studies have alleged that the black carbon emitted from traditional stoves can have adverse environmental impacts (Ramanathan and Carmichael 2008).

Labeled as the "other energy crisis" in the 1970s, such health and environmental issues had gone virtually unnoticed for thousands of years (Eckholm 1975). Today, such patterns of household energy use and local fuel collection linked to poor health and local environmental pressure are well recognized by most policy makers.

Benefits of Clean Cooking

Many of the benefits of employing clean cooking methods are quite obvious.[27] First and foremost are the savings in cooking fuel and time. Improved cookstoves can be 40–50 percent more efficient than their counterpart traditional or open-fire stoves. The substantial fuel savings can mean more disposable income for households. Secondly, cooking with improved cookstoves or commercial fuels (e.g., LPG) is faster than preparing food with traditional stoves. The time savings refers to both cooking time and time spent collecting fuelwood or other local energy sources. Fuel collection, which is often done by women and children, involves walking long distances. The drudgery of carrying loads of fuel back home to cook evening meals may take hours.

The benefits of moving away from traditional cooking patterns are many and entail several dimensions. Women's time savings can be reallocated from cooking and fuel collection to more productive and satisfying activities (e.g., income generation, childcare and tutoring children, reading, watching TV, entertainment, and socializing), while children's time savings can be redirected from fuel collection to studying. Moving away from traditional cooking methods also promotes better health since cleaner cooking methods produce less smoke and indoor air pollution (IAP) compared to traditional stoves. Finally, cleaner cooking methods have implications for climate change. The more efficient burning of biomass fuels with the use of improved cookstoves reduces GHG emissions and may contribute to mitigating global warming. Widespread dissemination of cleaner cooking methods can also reduce deforestation.

A number of studies have shown the benefits of clean cooking over traditional methods. One study found that fine particulates found in the kitchens of rural Ghana were reduced by 52 percentage points when traditional stoves were

[27] Clean methods of cooking include improved biomass cookstoves, high-pressure kerosene stoves, and LPG stoves. In this chapter, the term *improved cookstove* refers to all methods of clean cooking.

replaced by the Gyapa improved stove (Pennise et al. 2009). That same study found that introduction of an ethanol stove in the kitchens of rural Ethiopia reduced $PM_{2.5}$ concentrations by 84 percentage points. Another study, conducted in Guatemalan villages in 1993–94, found that concentrations of CO and $PM_{2.5}$ were higher for open-fire cooking (at 22.9 ppm and 5.31 mg per m^3, respectively) than for gas stoves (at 3.5 ppm and 0.13 mg per m^3, respectively) (Naeher et al. 2000). A more recent study in rural Madagascar comparing traditional and improved cookstoves using wood fuel found that the improved cookstoves reduced CO concentrations in the kitchen by 69 percentage points (Dasgupta, Martin, and Samad 2015). Some literature links the use of clean cooking methods to a reduction in fuelwood consumption. For example, a study conducted in Burkina Faso found that a 28 percent reduction in fuelwood use could be attributed to the use of improved cookstoves (Bensch, Grimm, and Peters 2015). The use of LPG and other commercial fuels can have similar impacts. More generally, a global study recognizes household IAP from solid fuel use as a leading risk factor for global burden of disease. Smith et al. (2014) finds that IAP, caused mainly by smoke emitted by traditional biomass cookstoves, accounts for an estimated 3.7 million premature deaths each year, making it the second leading cause of disease behind smoking.

Quantitative Technique

Cleaner forms of cooking include the adoption of both improved cookstoves and modern cooking fuels. Both technologies have the impact of reducing cooking time, collection time of traditional fuel, and IAP. While this section focuses on improved biomass cookstoves (ICS), it should be noted that other methods of clean cooking (e.g., LPG and high-pressure kerosene stoves) may have the same or even greater benefits.

The impacts of adopting improved cookstoves can be assessed using a regression-based approach similar to those used to assess the benefits of electricity. However, households with improved cookstoves may also use other stoves that are even cleaner (e.g., LPG stoves), as well as traditional cookstoves, making benefit estimation a bit complicated. This situation differs from that of access to electricity, where households usually have access to one source only or no access. Unless a distinction is made among the types of stove owners, the estimated benefit of improved cookstoves would be difficult to measure.

This means that an equation for measuring the benefits of clean cooking interventions must take into account other types of stoves. While the number and types of stoves are country-specific, mutually exclusive categories of cookstove owners' use can be found in many countries as follows:[28]

- Traditional stoves only,
- Improved biomass stoves only,
- Kerosene stoves only,
- LPG stoves only,
- Combination of stoves including traditional stoves, and
- Combination of stoves not including traditional stoves.

Prior to conducting a survey, it is important to define the main groups of stoves used in a particular country. In this way, it is possible to measure not only the effects of improved biomass cookstoves over traditional ones, but also the effects of other clean cookstoves (i.e., those that use LPG and kerosene).

With these six categories in mind, the general form of the equation can written as follows:

$$Y = \alpha X + \beta V + \gamma H_{ICS} + \delta H_K + \chi H_L + \rho H_{COMB\_TR} + \lambda H_{COMB\_NOTR} + \varepsilon, \qquad (7.1)$$

where Y is the outcome of interest; X is the set of standard household variables (e.g., age and education of household head) and additional control variables relevant to cookstoves and cooking practices (box 6-1 and figure 7-1); V is the set of community variables (e.g., population, size of village, and infrastructure) (box 6-2); and H variables refer to all of the above-mentioned cookstove owners, except for "traditional stoves only." Exclusion of the traditional-stoves-only category from equation (7.1) means that the parameters γ, δ, χ, ρ, and λ capture the incremental benefits of various other stove ownership types over traditional-stove-only ownership. Equation (7.1) can thus be used to assess the impacts of improved and clean cookstoves on outcomes of interest.

[28] It should be noted that this list is not exclusive. For example, electric stoves (induction or other types) are common in many developed countries.

Cooking and Kitchen Characteristics

As mentioned, the general equation for the clean cooking intervention requires additional control variables (X) beyond the standard ones. These include stove features and cooking behavior, kitchen, and stove dealer characteristics. Beyond the standard household characteristics, these additional control variables can affect stove performance, and should be included in all outcome equations. For example, age of the cookstove or its maintenance can have an effect on cooking performance.

For clean cooking, it is necessary to collect information on the types of stoves used for cooking. Since households generally use more than one type of stove, this question has multiple responses. Figure 7-1 illustrates one way of phrasing the questions on electricity use, while other examples are found in Annexes A–C.

The type of fuel used determines the amount of heat generated during cooking. The kitchen size has an impact on the level of IAP. Also, the stove dealer may play a role in whether households correctly use and maintain the

Figure 7-1. Questions related to stove adoption

Improved Biomass Cookstove (ICS) Adoption

Q3.3 Please describe all types of cookstoves that the household has.

Cookstove possible responses:

Stove	Type
1	
2	
3	
4	
5	

1 = Traditional 3-Stone
2 = Traditional 5-Stone
3 = Open Fire
4 = ICS Type 1
5 = ICS Type 2
6 = ICS Type 3
7 = ICS Type 4
8 = Kerosene Wick
9 = Kerosene Pressure
10 = LPG Stove
11 = Other (Specify________)

Source: This study.
Note: The questions shown in this figure are illustrative; in practice, stove types will vary by country. Information should also be collected on other cooking practices that use kerosene and LPG. Questions related to electricity use will also vary, depending on the particular country situation.

Figure 7-2. Questions to collect information on additional control variables for improved cookstove outcome equations

Improved biomass cookstove characteristics	
Q7.1	How old is the improved biomass cookstove (ICS)? (months)
Q7.2	Is the ICS your main stove? (1 = YES, 0 = NO)
Q7.3	What fuel do you use mostly in the ICS? (1 = Firewood, 2 = Crop Residue/Leaves, 3 = Animal Waste/Dung, 4 = Sawdust, 5 = Charcoal, 6 = Coal, 7 = Other [Specify_______________])
Q7.4	Do you clean your ICS regularly? (1 = YES, 0 = NO)
Q7.5	Does your ICS have a chimney? (1 = YES, 0 = NO)
Q7.6	If you have both ICS and traditional stoves, what percentage of time do you use the ICS? (%)
Q7.7	If you have both ICS and traditional stoves, do you use them simultaneously? (1 = YES, 0 = NO)
Q7.8	Did you receive any training on the proper use of the ICS? (1 = YES, 0 = NO)
Kitchen characteristics	
Q7.9	Where does the household usually cook? (1= Separate Kitchen (Covered), 2 = Separate Kitchen (Uncovered), 3 = Main House In A Separate Room, 4 = Main House In The Dining Area, 5 = Main House In Sleeping Room, 6 = Other [Specify_______________________________])
Q7.10	What is the length of the kitchen? (meters)
Q7.11	What is the width of the kitchen? (meters)
Q7.12	What is the height of the kitchen? (meters)
Q7.13	Do you have ventilation, windows, or other openings in your kitchen? (1 = YES, 0 = NO)
Dealer characteristics	
Q7.14	What is dealer's sex? (1 = male, 0 = female)
Q7.15	What is dealer's age? (years)
Q7.16	What is dealer's experience in the ICS business? (years)
Q7.17	Does the dealer have a registration for the ICS business? (1 = YES, 0 = NO)
Q7.18	Is the ICS business the main occupation of the dealer? (1 = YES, 0 = NO)
Q7.19	What is the dealer's monthly income from the ICS business? ($)
Q7.20	Does the dealer provide a warranty for the ICSs he or she sells? (1 = YES, 0 = NO)

stove. Households usually get their improved stoves from the local dealer and do not have much choice. Figures 7.2–7.4 illustrate the types of sample questions required to analyze the impact of clean cooking methods, measure the stoves' age and condition, types of fuel used, kitchen size and ventilation, and other variables.[29]

Figure 7-3. Simplified household fuel-use questions

1. Do you use any of the following energy sources for cooking lighting or winter heating? *(Code: No = 0 go to next fuel, Yes = 1. If yes ask questions to the right)*	**2. How many days in the last week did you use this fuel for cooking or lighting?** *(Code: 0 for did not use and 1-7 for days of the week)*		**3. During a typical winter week, how many days did you use this fuel for heating?** *(Code: 0 for did not use and 1-7 for days a week)*
1.a Fuelwood ____ (Yes/No) If yes ------->	2.ca _____ Cooking	2.la _____ Lighting	3.a _____ Heating in winter
1.b Dung ____(Yes/No) If yes ------->	2.cb _____ Cooking	xxxxxxxxxxx	3.b _____ Heating in winter
1.c Straw/Stalk ____(Yes/No) If yes -------	2.cc _____ Cooking	2.lc _____ Lighting	3.c _____ Heating in winter
1.d Charcoal ____(Yes/No) If yes ------->	2.cd _____ Cooking	xxxxxxxxxxxx	3.d _____ Heating in winter
1.e Kerosene ____(Yes/No) If yes ------->	2.ce _____ Cooking	2.le _____ Lighting	3.e _____ Heating in winter
1.f LPG ____(Yes/No) If yes ------->	2.cf _____ Cooking	2.lf _____ Lighting	3.f _____ Heating in winter
1.g Electricity ____(Yes/No) If yes ------->	2.cg _____ Cooking	2.lg _____ Lighting	3.g _____ Heating in winter

Source: This study.

[29] These questions are for the purpose of demonstration. Actual questions will depend on the specific country and local context.

Figure 7-4. Characteristics of biomass stove questions

4. For those using fuelwood, straw, stalk, or dung for cooking in household fuel questions, is the stove:	**Responses and Codes**
4a. Open or closed?	_______*Code: Open = 1, closed 2*
4b. Made out of stones, clay, or metal?	_______*Code: Stones = 1, clay = 2, metal = 3*
4c. Self, local artisan, or factory made?	_______*Code: Self-made = 1, artisan-made = 2, factory- made = 3, don't know = −9*
4d. With or without a chimney?	_______*Code: With a chimney = 1, without a chimney = 2.*
4e. Located inside or outside of the house?	_______*Code: Inside = 1, outside = 2, both (portable stove) = 3*
5. For those using charcoal for cooking, is the stove self, artisan or factory made?	_______*Code: Self-made = 1, artisan-made = 2, factory-made = 3, don't know = −9*
6. For those using kerosene, is the main stove a kerosene or wick type?	_______*Code: Wick = 1, pressure = 2*
7. For those using LPG for cooking, how many burners are on the stove?	_______*Code: Number of burners*
8. For those using electricity for cooking, how many burners are on the stove?	_______*Code: Number of burners*

Source: This study.
Note: These stove questions could also be asked in the appliances section.

Time-Savings Benefits

One of the foremost benefits of clean cooking, compared to traditional cooking, is time savings. The time saved, particularly for women, can be used for such activities as taking care of children; helping children with their studies; watching TV and listening to radio for news and information, knowledge, and entertainment; and engaging more in income-generating activities.

Equation (7.1) can be rewritten for fuel collection time as follows:

$$T_{FC} = \alpha X + \beta V + \gamma_{FC} H_{ICS} + \delta_{FC} H_K + \chi_{FC} H_L + \rho_{FC} H_{COMB\_TR} + \lambda_{FC} H_{COMB\_NOTR} + \varepsilon, \tag{7.2}$$

where T_{FC} is the time spent (in hours) by all household members in collecting fuels during the last 30 days; H-variables capture different types of stove owners excluding traditional-stove-only type (subscripts denote the stove-type), and the parameters γ, δ, χ, ρ, and λ capture the impacts of various stove ownership types on fuel collection time.

Similarly, the equation for cooking time is given by the following equation:

$$T_{CK} = \alpha X + \beta V + \gamma_{CK} H_{ICS} + \delta_{CK} H_K + \chi_{CK} H_L + \rho_{CK} H_{COMB\_TR} + \lambda_{CK} H_{COMB\_NOTR} + \varepsilon. \quad (7.3)$$

From equations (7.2) and (7.3), the total effects of ICS-only households on time savings per month is expressed as follows:

$$\gamma_{ICS} = \gamma_{FC} + \gamma_{CK}. \quad (7.4)$$

Then the monetary benefits per month from the time saved due to ICS adoption is given by the following:[30]

$$V_{ICS\_TS} = (\gamma_{ICS}/8) * W, \quad (7.5)$$

where W is the prevailing daily wage in the community. The division by 8 is needed to convert hours saved per month to days saved per month.

Measuring Variables for Time Savings

The adoption of electricity can result in time savings from decreases in fuel collection and cooking time. This means that questions on these topics must be asked in order to accurately measure the changes in cooking resulting from electricity (figure 7-5). The questions should contain information for both men and women. It is often assumed that only women and children are responsible for fuel collection. It is true that women generally spend more time collecting fuel compared to men. However, many surveys have shown that that men do collect wood and other biomass fuels for cooking, especially when the travel distances involved become large.

[30] A more accurate estimation is possible by (i) separately estimating time saved for men, women, and children; (ii) multiplying them by the respective prevailing wages; and (iii) aggregating all monetary benefits. The simplified version shown here applies the same wage for men, women, and children.

Figure 7-5. Questions on time savings in fuel collection and meal preparation

Fuel collection (for all household members that collect fuel)	
Q7.21	(For all men age > 15) How much time was spent in fuel collection during the last 7 days (total time for the round trip and fuel collection)? (hours)
Q7.22	(For all women age > 15) How much time was spent in fuel collection during the last 7 days (total time for the round trip and fuel collection)? (hours)
Q7.23	(For all boys age ≤ 15) How much time was spent in fuel collection during the last 7 days (total time for the round trip and fuel collection)? (hours)
Q7.24	(For all girls age ≤ 15) How much time was spent in fuel collection during the last 7 days (total time for the round trip and fuel collection)? (hours)
Cooking (for all household members that cook)	
Q7.25	How much time is spent (in total) cooking by all members on an average day? (hours)

Source: This study.
Note: Alternate ways of posing questions on time savings for cooking and fuel collection are provided in Annexes A–C.

With the information from responses to these questions, the equations for time savings for cooking and fuel collection can be written as follows:

$$T_{FC} = (Q7.21 + Q7.22 + Q7.23 + Q7.24) * 4.3$$

$$T_{CK} = Q7.25 * 30.$$

Income Benefits: Energy Expense and Time Savings

Households can improve their available income from clean cooking in several ways. Of course, these benefits must be measured against their cost. The cost of clean cooking would involve the purchase of an improved biomass, kerosene, or LPG stove. For kerosene and LPG stoves, the household would also have monthly fuel expenditures. Once the savings in time spent on collecting fuel and cooking are calculated, these savings must be measured against the cost of adopting clean methods of cooking. In this section, the cost of adopting clean cooking methods is not detailed; however, its importance in assessing the monetary benefits of clean cooking should be kept in mind.

Clean methods of cooking generally result in biomass fuel savings. The adoption of LPG, kerosene, or improved stoves for cooking means that less biomass fuel will need to be collected or purchased to cook the same amount of food. The savings in firewood can sometimes be quite substantial, depending on the efficiency of the new stove and its use. If wood and other biomass fuels are purchased, this savings can mean a direct increase in disposable household income. If the biomass fuel is collected, it means a decrease in time spent collecting fuels for use in the traditional stove. The opportunity cost of this time is typically valued at the local cost of manual labor.

Many studies have shown that electricity, combined with clean cooking, leads to a reduction in cooking time. The time savings could be substantial, particularly for women, as previously discussed. The value of women's reallocated time use (e.g., starting a new business or caring for children) would be hard to measure, so once again the time savings could be valued at the local cost of manual labor.

The value of reducing biomass fuel consumption can be estimated through a regression of the fuel saved by various methods of clean cooking. Again, the outcome equation for fuel consumption can be written, similar to equation (7.1), as follows:

$$F_Q = \alpha X + \beta V + \gamma_Q H_{ICS} + \delta_Q H_K + \chi_Q H_L + \rho_Q H_{COMB\_TR} + \lambda_Q H_{COMB\_NOTR} + \varepsilon, \quad (7.6)$$

where F_Q is the firewood or other biomass consumption for cooking (in kg) by the household in the last 30 days; H_{ICS}, H_K, H_L, H_{COMB_TR}, and H_{COMB_NOTR} are household ownership of ICS-only, kerosene stove-only, LPG stove-only, multiple types of stoves including traditional stoves, and multiple types of stoves excluding traditional stoves, respectively. That is, the excluded category is households who own traditional stoves only. The coefficients of H-variables— γ_Q, δ_Q, χ_Q, ρ_Q, and λ_Q—capture reductions in fuel consumption (in kg per month) for the aforementioned stove owners over owners of traditional stoves only.

Many households in developing countries use firewood. But other types of biomass fuels, including crop residues, dry leaves, and animal waste and dung, are also commonly used. Depending on the particular country context and fuel used in rural areas, separate outcome equations for these fuels can be estimated for completeness.

The monetary benefit from such a reduction in fuel consumption can be calculated by multiplying the quantity of firewood saved per month (in kilograms) by the price of firewood in the local market. This calculation is expressed by the following equation:

$$V_{ICS\_Q} = \gamma_Q * P_{FW}, \tag{7.7}$$

where P_{FW} is the local price of firewood ($ per kg).

If the time saved by women in preparing food is substantial, then the techniques illustrated in the section on time savings can be used to calculate the monetary gain. Again, the monetary value of the time savings can be calculated by using the local cost of manual labor. It should not be forgotten that additional costs are necessary in adopting clean cooking methods. The additional costs of clean cooking must be subtracted from the value of fuel or time savings in order to arrive at an overall value of clean cooking.

Health Impacts

The health benefits of clean cooking result from the reduction in smoke emitted during cooking. This is partly the result of reduced consumption of firewood and other biomass fuels and partly due to more complete fuel combustion. The use of firewood in traditional stoves leads to incomplete burning of fuels, which releases small particles and other constituents (mostly $PM_{2.5}$ and CO) that are harmful to human health. Stoves used for clean cooking are more efficient, causing less smoke emissions and other harmful particles.

The reduced incidence of illnesses related to IAP (e.g., coughing, sneezing, chest pain, and eye irritation) can be used to measure the health impacts of clean cooking. As earlier discussed, the approach for measuring the impact of clean cooking on health is similar to that used to measure the health impacts of adopting electricity. However, the analysis of health benefits is quite complicated since there can be many causes of disease. Therefore, it is better to leave the analysis of health benefits to a more dedicated survey with many more questions on this topic.

Conclusion

The literature on clean cooking has focused on health issues. Most programs to reduce IAP have other major benefits for households, especially for women (e.g., reduction in time spent on fuel collection and cooking and lower cooking fuel expenditures). These types of benefits accumulate daily or weekly and can add up to substantial amounts over the course of a year or more. In fact, the monetary value of such benefits may equal or exceed those for health. Unfortunately, only a few studies have tackled translating the benefits of saved time and expenditure into monetary values. This is an area of research that needs to be increased in order to justify the expense of implementing programs involving better stoves and fuels for households that depend on using biomass in traditional stoves for cooking.

Chapter 8
Under-Measured Benefits of Energy Access

The benefits of changes in energy access typically occur at the household or community level. The benefits reviewed in the previous chapters of this study include better education, cleaner cooking, and a higher quality of household lighting, among others. Beyond these, however, there is another class of benefits that is harder to measure. Many people are concerned that, as households switch from renewable biomass to commercial fuels, this increase in energy access may increase the level of harmful pollutants emitted into the atmosphere. While partially true, the gain in energy efficiency from moving away from traditional fuels means that households use less biomass or petroleum fuels. Nearly 2 billion people without electricity use polluting kerosene lamps, as well as candles and other inferior types of lighting. With a switch to electricity, the overall pollution levels may decline despite the higher service levels. The greater efficiency of modern fuels might actually lead to environmental benefits.

Environment

Many poor countries are not acknowledged as a significant source of greenhouse gases (GHGs) because they use little commercial energy. This is not the case for some of the larger countries, such as India and China, where economic growth is driving higher levels of use of commercial energy, such as coal. Significant economic growth is generally accompanied by growth in the use of commercial and modern energy, along with increases in GHG emissions. In Africa, 80–90 percent of total energy use consists of burning wood and other biomass fuels. The reliance of small, poor countries on traditional fuels is not a central focus of the climate change debate. Not surprisingly, most programs to alleviate carbon emissions are targeted toward the larger countries where carbon emissions are already quite high.

Most climate change studies ignore collected cooking fuels in their scenarios simply because it is easier to estimate the contributions of coal and other commercial fuels to increasing pollutants in the atmosphere. The climate debate appears to have a single-minded focus on carbon dioxide (CO_2) emissions from commercial fuels, along with such agents as methane and other GHGs. The focus on large countries with significant commercial development risks crowding out attention on poorer, low-income developing countries, where there are under-recognized co-benefits of jointly addressing energy access and climate change.

About half of the people in developing countries—and more than 90 percent of rural residents in many countries—use biomass energy (e.g., wood, dung, and agricultural residue) as their main fuel sources for cooking and heating. For the 2.5 billion people who rely on biomass energy, collecting biomass for cooking is an arduous task that causes indoor air pollution (IAP) and leads to pressure on local biomass resources. Biomass energy is also collected from the local environment, most often by women, and this time-consuming activity takes time away from productive and family activities, as previously discussed. Cooking fuel is seldom considered in the climate change debate, yet some 730 million tons of biomass are burned in developing countries each year (WHO 2007), amounting to over 1 billion tons of CO_2 emitted into the atmosphere. If the use of biofuels in developed countries for all purposes is added to the massive quantities of fuelwood burned in developing countries, the total biomass use for energy is estimated at about 2–2.5 billion tons (Yevich and Logan 2003; Fernandes et al. 2007).[31] In addition, other products of incomplete combustion have large GHG impacts. One could argue that some of the emitted CO_2 is sustainable because the biomass re-grows; however, the amount of regrowth is open to question. With better fuels and more efficient stoves, this number could be reduced dramatically.

Given the low levels of energy used in developing countries and their not unrelated low levels of development, it is not surprising that low-income countries want to follow both developed and advanced developing countries (e.g., China, India, and Brazil) in their quest for a better way of life. The basic

[31] Heating would add even more to this figure. In terms of lighting, developing countries burn about 11.5 million tons of kerosene each year in what amounts to tins with a wick. These fuels are inefficiently burned and, because of incomplete combustion, produce other GHGs that stay in the atmosphere for decades (WHO 2007; Smith 2000).

relationship between GDP growth and increased energy use has been well documented (Modi et al. 2006). However, some new evidence suggests that such programs as rural electrification do cause an increase in income and welfare. Thus, the question is this: How does one reconcile mitigating climate change with the reality that so many people around the world are aspiring to higher levels of economic well-being, which would lead to greater energy use and, all else equal, increased GHG emissions.

Perhaps the silver lining in this dilemma is that switching to more modern use of energy involves significant changes in energy efficiency. This type of change has been documented in India, where a national survey collected information on fuel use and its relationship to income (Khandker et al. 2014). Households at the lowest income levels were found to use energy less efficiently than those at higher income levels because of their inefficient use of biomass fuels. The poor in India cook on wood stoves with barely 15 percent efficiency levels, while households with higher incomes cook with LPG, with efficiency levels of 65 percent or higher. The actual efficiency ratios follow this pattern, with wealthier households using about the same amount of fuel as lower-income households but getting double to triple the amount of useful energy.

Thus, if poor and middle-class households adopted more efficient cooking methods, it might be possible to reduce their emissions considerably. This could be done by introducing more modern methods of cooking, heating, and lighting. Most of the energy savings would probably accrue to the more populous middle-income groups, who still depend on biomass energy for much of their cooking needs. However, the affordability issue involved would mean such households would require some form of financial incentives. Climate change policies have not addressed the problems of these households, which continue to burn fuels and emit carbon into the atmosphere using primitive stoves amounting to nothing more than open fires.

Reduction in Kerosene Use

A reduction in kerosene consumption for lighting lowers IAP, which is a household-level benefit. The reduction in kerosene burning is also a societal or global benefit, given its enormous, accumulated effect on global warming. It is estimated that the global consumption of kerosene for lighting may be as high as 65 million tons a year (Lam et al. 2012b). Recent research shows that kerosene lamps emit 20 times more black carbon than previous estimates and thus the global warming impact is orders of magnitude higher than what was previously calculated (Jacobson et al. 2013). Similarly, the adoption of improved biomass stoves reduces firewood consumption and significantly lowers CO_2 emissions. Black carbon, which is emitted from kerosene lamps, is also emitted from the incomplete burning of firewood in traditional stoves.

Household savings in kerosene consumption resulting from household electricity adoption can be useful for calculating the reduction in CO_2 emissions. While other GHGs are also released through burning kerosene, CO_2 is considered the largest contributor to global warming. Calculating the reduction in kerosene consumption from household electricity adoption can be expressed by the following equation:

$$Q_K = \alpha X + \beta V + \delta_Q H_{ELEC} + \varepsilon, \tag{8.1}$$

where Q_K is the household's monthly consumption of kerosene (liters), X is the set of mandatory household variables (e.g., age and education of household head) (box 6-1); V is the set of mandatory community variables (e.g., population, size of village, and infrastructure) (box 6-2); and parameter δ_Q is the effect of electrification on kerosene consumption.

The results of this equation mean that, with the adoption of electricity, household kerosene consumption falls by δ_Q liters per month. This reduction in kerosene consumption can be translated into a reduction in CO_2 emissions, expressed as follows:

$$Q_{CO2\_ELEC} = \delta_Q * 2.5 * 12 * N_{HELEC}/1000 = 0.03\delta_Q N_{HELEC}, \tag{8.2}$$

where Q_{CO2_ELEC} is the reduction in CO_2 for the country (tons per year), 2.5 is the factor for converting liters of kerosene into kilograms of CO_2, 1,000 is the factor for converting kilograms to tons, and N_{HELEC} is the number of households adopting electricity.

Similarly, household savings in firewood consumption from adoption of clean cooking methods can be used to calculate the reduction in CO_2 emissions. For improved biomass stoves, the direct reduction in CO_2 emissions parallels the greater efficiency of the stove. However, for such fuels as kerosene and LPG, the CO_2 emitted by cooking with those fuels must be subtracted from the total emissions of cooking with a traditional stove. It was demonstrated in chapter 7 (in equation 7.6) how to estimate savings in firewood consumption from adoption of improved cooking. The reduction in firewood consumption can be translated into a reduction in CO_2 emissions, using the following equation:

$$Q_{CO2\_ICS} = * 1.73 * 12 * N_{HELEC}/1000 = 0.03\delta_Q N_{HELEC}, \tag{8.3}$$

where Q_{CO2} is the reduction in CO_2 for the country (tons per year), 1.73 is the factor for converting kilograms of firewood into kilograms of CO_2, 1,000 is the factor for converting kilograms into tons, and N_{HELEC} is the number of households with electricity in the country.

Policies with a positive impact on income growth within poor countries will lift people out of poverty. Conversely, investments in climate change may make it more difficult for such poor countries to grow and prosper. In fact, linking macro issues like climate change to such micro issues as energy poverty is difficult once you go beyond the stage of saying economic growth and reduced climate change are good for everyone. Thus, a more direct approach that deals with both demand-side issues and the energy transition might be a better way to handle the issue of climate change and the poor. To date, it has been quite difficult for the energy poor to gain access to the carbon credits available for alleviating CO_2 emissions—resources that could also be used to lessen energy poverty. A more concerted effort in helping the poor use fuels in more efficient and sustainable ways can be important for both poverty alleviation and climate-friendly economic growth.

Women's Time Use and Empowerment

Household energy is extremely important for women. In fact, women benefit more from energy access programs than from most other investments in infrastructure development. The reason is that household electricity enables women to take advantage of labor-saving devices. Also, because women spend more time physically inside the home than do men, they are able to benefit more from the adoption of electricity. Women cook most of the family meals and thus benefit more from reduced levels of IAP after adopting clean methods of cooking. Without better stoves or fuels, women are exposed to the harmful pollutants associated with using biomass fuels in traditional stoves. Women also

Figure 8-1. Women's time-use questions

		PID
Q8.1	How much time do you spend cooking per day? (MINUTES)	
Q8.2	How much time do you spend in childcare and helping in children's study per day? (MINUTES)	
Q8.3	How much time do you spend reading per day? (MINUTES)	
Q8.4	How much time do you spend listening to radio or watching TV per day? (MINUTES)	
Q8.5	How much time do you spend socializing per day? (MINUTES)	
Q8.6	How much time do you spend on income-generating activities per week? (MINUTES)	
Q8.7	How much time do you spend shopping per week? (MINUTES)	

Source: This study.
Note: These questions are for women ages 15–49. For alternate questions, see Annex C.

benefit from the reduced cooking time that comes with better household lighting and stoves, including those that burn LPG and other modern fuels.

Measuring the benefits of energy access for women requires that surveys have questions on women's time use and empowerment. Electrification and adoption of clean cooking methods free up women's time for other activities. Having electrification in the household allows women to access news and information and gain knowledge through a variety of electricity-powered media (i.e., radio, TV, and computer) (figure 8-1). This, in turn, may result in a higher value of self-worth in society as a whole, which theoretically, at least, leads to women's empowerment. Moreover, electricity access may well have an impact on women's time allocation, meaning that they abandon time-consuming drudgery and household chores and engage in more productive and satisfying activities.

The regression framework can be used to measure the effects of electrification on women's time spent in productive or otherwise rewarding activities, as follows:[32]

[32] This exercise focuses on assessing the impacts on women's time use resulting from electrification; the impacts from the use of improved cookstoves can similarly be assessed.

$$T_{PRD} = \alpha X + \beta V + \delta_T H_{ELEC} + \varepsilon, \tag{8.4}$$

where T_{PRD} is the woman's time spent on useful activities (minutes), and parameter δ_T is the effect of electrification on time use.

In assessing women's time use, questions can be asked for a range of productive or beneficial activities over the course of a day (figure 8-1 and additional question in Annex C). Energy access is expected to affect such activities as cooking, taking care of children, entertainment, and income-generating activities.[33]

For developing countries, women's empowerment is usually measured in terms of their mobility, decision-making in household affairs, and ability to purchase various goods. Energy access raises the level of awareness of customs and traditions beyond communities. It is quite possible that this may raise women's levels of empowerment. Again, the outcome equations for various indicators of women's empowerment can be written as follows:[34]

$$I_{EMP} = \alpha X + \beta V + \delta_I H_{ELEC} + \varepsilon, \tag{8.5}$$

where I_{EMP} is the women's empowerment indicator (dummy variable) and parameter δ_I is the effect of electrification on the empowerment indicator.

The measures of empowerment may include freedom to travel outside the house, decision-making in household issues, and ability to purchase household goods (figure 8-2). Again, these measures are hard to quantify in monetary terms, but they are worth pursuing due to high interest in the impact of modern energy for women.

Public Lighting

Another benefit of energy access from which the overall community, as opposed to individual households, benefits is public lighting. Street and other forms of public lighting provide a sense of security for all community residents that are

[33] It should be cautioned that modern energy access is important for various aspects of time use, many of which cannot be given a monetary value.

[34] While this exercise is for assessing electrification impacts on women's time use, similar impacts can also be assessed for the impacts of improved cookstoves using the relevant equation.

Figure 8-2. Women's empowerment questions

		PID
Q8.8	Can you go to markets alone without asking for permission? (1 = YES, 0 = NO)	
Q8.9	Can you go to banks alone without asking for permission? (1 = YES, 0 = NO)	
Q8.10	Can you visit friends and relatives alone without asking for permission? (1 = YES, 0 = NO)	
Q8.11	Can you go to town alone without asking for permission? (1 = YES, 0 = NO)	
Q8.12	How do you decide on children's education? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify_______________])	
Q8.13	How do you decide on children's marriage? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify______________ _])	
Q8.14	How do you decide on children's healthcare? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify_______________])	
Q8.15	How do you decide on purchasing own personal items? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify_______________])	
Q8.16	How do you decide on purchasing small household items? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify_______________])	
Q8.17	How do you decide on purchasing large/expensive household items? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify_______________])	
Q8.18	How do you decide on purchasing children's items? (1 = Decide Alone, 2 = Decide with Husband, 3 = Decide with Other People, 4 = Cannot Decide, 5 = Other [Specify_______________])	

Source: This study.
Note: These questions are for women ages 15–49. For alternate questions, see Annex C.

covered. While existing studies on the effects of street lighting focus mainly on crime reduction, other benefits include improved safety for pedestrians and drivers. Valuation of the benefits of public lighting is difficult since there is no established way to assign value to reduction of crime in a community.

Potable Water

Electricity is an important input for maintaining a healthy supply of drinking water. In most developing countries, rural water supplies rely on electric pumps to lift water from safe sources into tanks or other storage units. This water is then piped to households in the community or community taps. But the benefits of electricity are difficult to measure since they are an input in other programs.

Conclusion

Moving households up the energy ladder to more modern forms of energy use can be achieved in a variety of ways. What remains uncertain are the development benefits relative to costs and the net impacts on GHGs. The goal of alleviating poverty is central to international efforts to promote development. Yet little information is available on the energy poor and how their energy-use patterns relate to energy development and climate change. Large-household-budget or quality-of-life surveys measuring income and poverty often omit all but the most basic energy questions. In order to understand the relationship between energy poverty and climate change, it would be necessary to develop better information on energy use by the poor and how this is impacted by climate change and how climate change induces energy use.

Chapter 9

Conclusion: Energy Access and Measurement Issues

Many of the individual benefits of energy access, as measured by the various methods covered in this handbook, cannot be added together. Some of the benefits might be counted twice or even several times. For example, the measurement of consumer surplus for household lighting may have embedded in it the expectation that children will have the opportunity to study longer hours and attain higher levels of education. The desire for lighting may also be due to the possibility of opening a small store or working on handicrafts during evening hours. Consumers may want better-quality lighting for multiple reasons. This chapter discusses how and to what extent the monetary benefits of energy access can be combined to arrive at an overall benefits assessment.

Evaluating the Benefits of Electricity

The two major ways to assess the benefits of electricity access include the consumer surplus and regression approaches. Each one has strengths and weaknesses. The consumer surplus approach focuses on demand and use of specific appliances. It also provides a general measure of monetary benefits. The benefits measured by consumer surplus might include those from watching television, listening to radio, having a refrigerator, and using a fan. They all measure the various aspects of quite distinct activities. The regression approach takes a more direct route toward measuring the benefits of electricity. The results of the regression might include the educational attainment, additional business hours, and increased income. These benefits then need to be translated into monetary terms. In this section, we summarize some of the main features of each approach.

Consumer Surplus Measures End-Use Services

The value of all individual services as measured by consumer surplus are based on services provided by specific appliances; therefore, they can be added together to arrive at an overall value for these services. The value of higher-quality lighting is that it enables socializing, productive uses, and reading. The value of better entertainment can be estimated by examining people's use of radios and television sets for households with and without electricity. The value of cooling can be assessed through the willingness to purchase fans, refrigerators, or even air conditioners. Finally, the value of having computers—although difficult to estimate given the uniqueness of the appliance—can be assessed using contingency valuation (CV), in which case it can be added to the other benefits of energy access. Most all of these benefits can be added together to arrive at the overall value of energy access.

For good reason, electric lamps are among the first appliances adopted by households that are just gaining access to electricity. Lighting captures many benefits, including socializing, reading, studying, education, and productive activities. While far from perfect, it is one of the most comprehensive measures of improved welfare for households adopting electricity.

The desires for televisions and radios are somewhat overlapping since both media measure the benefits of information and entertainment. Generally, it is found that, after adopting electricity and purchasing a television set, the time households previously spent listening to radio decreases. But for households without TVs, radio listening still provides entertainment, news, and information. For communities first receiving electricity, the wide variety of programming provided through TV has the effect of raising awareness of regional, country, and world events. For the same households, television and radio provide different types of benefits so it is possible to add them together. However, since radio listening typically decreases in households that acquire television sets, care must be taken to understand their different uses.

Calculating the monetary value of using computers, refrigerators, and fans is a bit more problematic. In warm-climate countries, electric fans are among the most common non-lighting appliances for households with electricity. For households without electricity, fans are usually too expensive to run on batteries. Thus, for the services provided by fans, there is no lower level of service provided by an alternate technology. Thus, it is quite difficult to develop a demand curve for space conditioning. Eventually, when households move on to air conditioners, it would be possible to measure the willingness to pay (WTP) for space conditioning using fans and air conditioners. Using the CV method, it is possible to measure the WTP for fans; however, in such cases, the benefits would be limited to the operation and capital cost of the appliance.

Similarly, for refrigerators, CV techniques can be used to assess the WTP. But again, the monetary value would be limited to the purchase and operating costs of the appliance. However, an alternate approach for refrigerators would be to assess the benefits of avoided food spoilage. This would give the monetary value of the purchase and use of a refrigerator for food storage. Since this benefit is unique to refrigerators, it can be added to those of lighting, radios, and televisions.

Households without electricity do not have computers; thus, it is virtually impossible to make comparisons for changes in demand for computing power. If computers are found in households without electricity, then a demand curve could be developed based on the battery charges incurred by the household compared to the cost once electricity is adopted. Again, CV is a method that can be used to measure the value of computers for households with electricity, but it is an imperfect measure limited to the price and cost of operating a computer. The benefits of computing are so much higher due to the flexibility of electronic devices. For example, they can be used for streamlining work activities (e.g., billing and keeping track of sales), and, with Internet service, are a vast source of information and entertainment.

Cell phone use is nearly universal in many developing countries. Cell phones enable communication with friends and families, as well as access to information for household productive activities (e.g., markets) and even new activities (e.g., purchase of goods and services). Unlike television sets, cell phones are owned by many households without electricity, who must pay to have them charged. The value of cell phones, as for television sets, can be estimated using the WTP for service, including charges for both use and batteries. Because the cost of charging cell phones is less for households with electricity, it is quite possible to develop a demand curve for cell phones based on the cost paid by households with and without electricity.

Regression Approach Measures Outcomes

Compared to the consumer surplus approach, the regression approach is a more direct way of estimating the benefits of energy access. Instead of comparing the monetary demand of the same service before and after adopting electricity, the regression approach more directly assesses the impacts of electricity access. For example, the adoption of electricity may have an impact on increases in household income for a variety of reasons. Rather than estimating the value of one service, such as lighting, the regression approach controls for other important factors in evaluating the impact of having electricity on income or education. Because of causality issues, modelling the results can be quite complicated. For example, household education and income are often highly correlated, making it necessary to tease out the individual impacts of electricity for each of them. When using the regression approach, care must be taken to control for the right conditions to understand the relationship between energy access and development outcomes.

The main outcomes that have been evaluated using the regression approach are farm and nonfarm income, refrigerator ownership, kerosene consumption, household expenditures, and education (chapter 8). Many of these outcomes are overlapping. Obviously, total income can be derived from farm and nonfarm income. Of course, the measures of total income and total expenditure are quite similar. Modeling the impact of electricity on expenditures is often preferred over income because it is more stable over time. Income can fluctuate significantly from year to year due to losing a job, having a major farm expense, or experiencing lower retail sales when the economy dips. The use of expenditure as a proxy for income is a fairly common practice because of the sensitive nature of income information. Many surveys collect data on both income and expenditures. One or the other may be a better measure of financial well-being, depending on the country and the ways in which questions are asked of respondents.

Regression analysis can also be used to measure other impacts of electricity. For increases in education, for example, the value of each additional year of education can be valued through better paying jobs. The food saved by having a refrigerator can be valued in monetary terms. Avoided health costs can be modelled as a benefit of rural electrification. These and other uncounted savings can be added to form the total impact of electricity on overall development. But these topics can also be investigated in their own right to better understand the various means through which electricity access affects important development outcomes.

Evaluating the Benefits of Clean Cooking

The monetary benefits of clean cooking involve more complex benefits than those of electricity. Using cleaner fuels or improved biomass stoves can result in less time spent collecting fuel and cooking. However, studies have also found that electricity has a similar impact and may actually lead to changes in household behavior, such as adopting LPG or other cleaner methods of cooking. The reason is that higher-quality lighting means that people can cook in the evenings. Thus, it is necessary to model electricity in studies on the benefits of clean cooking. The avoided time spent collecting fuelwood is another benefit of clean cooking, which can be modelled by comparing households that do or do not employ clean cooking methods.

The health outcomes of clean cooking can model the values of avoided days lost due to illness and avoided treatment costs. These measures are very real benefits that can be measured in evaluating clean cooking. As previously indicated, evaluating health issues is a quite complex research task, involving numerous questions and intricate analysis exceeding the scope of most energy surveys; thus, it is best left to dedicated health surveys.

Unfortunately the health literature on clean cooking generally does not consider the social and economic benefits of shifting from traditional ways of cooking to more modern methods. The reason is that health professionals are more interested in the reduction of disease or disability-adjusted life years. Such aspects as time saved in cooking or changes in time use are typically not analyzed in any great detail. Yet, for many populations, these aspects of clean cooking may actually have a higher yearly monetary value than reduction in disease. The reason is that people may suffer health consequences only in future years. The negative impacts of cooking using traditional stoves may not be bad enough to impede productive work. By contrast, such activities as fuelwood collection are quite common daily or weekly tasks; thus, any reductions can add up to significant monetary values over the course of a year.

Which Approach Is Preferred?

The consumer surplus approach has been used successfully to capture benefits of energy access. The advantage of this approach is that it includes all the benefits of a purchased appliance. In expressing their willingness to pay, consumers provide an assessment of various types of services in monetary terms. By contrast, the regression approach attempts to measure benefits in terms of direct changes in outcomes. The question can be asked whether one approach is better than the other.

The answer is that, generally speaking, the regression approach is a more direct and accurate way of measuring the benefits of energy access. Using this approach, it is possible to control for other important and interrelated factors in order to tease out the specific impacts of energy access for development outcomes. The regression approach has also been the choice of impact evaluation specialists because of its flexibility in answering a wide range of questions. More specifically, properly structured impact evaluations can answer the following questions:

- Did the intervention work? That is, did it deliver the desired impacts?
- Were there negative impacts or unintended consequences?
- Did one or more components of the intervention work better than others?
- Were there other factors besides the intervention that influenced the impact?
- Was the impact short- or long-term?
- Who among the beneficiaries benefited the most from the intervention?
- Should the intervention be continued or scaled up?
- Can the intervention be replicated in another context?

The precision of the regression impact evaluation approach is tempered by the difficulty of carrying out such studies. The causality issues involved in impact evaluation research are always difficult to resolve. The statistical techniques are quite complex, involving many potential pitfalls. Even the most sophisticated studies have their drawbacks in sorting out the various causes of development outcomes. The reason is that many major development outcomes (e.g., income, health, and education) are interrelated. The task of a good impact evaluation is to discover the direct or indirect pathways through which energy access relates to each of these outcomes.

While the consumer surplus approach must also deal with causality issues, the analysis is somewhat less demanding. The reason is that this approach divides the development impacts into categories, based on the specific appliances being used. The use is discovered through household surveys specially designed to measure the monetary aspects of appliance use. For example, the demand for light comes from electric lamps, kerosene lamps, or candles. Diffuse development outcomes (e.g., education, reading, and productive activities, among others) are measured through consumer valuation of having better light in the household. Similarly, the demand curve for entertainment hours can be measured by the cost and use of batteries or plug-in radios. Thus, consumer surplus techniques for measuring demand for energy services are much less complicated. However, such factors as income and education do play a role in shaping consumer demand, and so should not be ignored.

The greater simplicity of the consumer surplus approach is balanced by the greater need for a household survey. The whole theory of consumer surplus is underpinned by accurately assessing demand for goods and services. As most people involved in product sales know, this is not a simple task. In fact, it requires comprehensive measurement of the cost or price of energy, hours of using appliances, and an understanding of the reasons for their use. Without accurately estimating the demand curve for such aspects as household lighting and entertainment, applying techniques to measure consumer surplus would lead to quite inaccurate results.

The strengths and weaknesses of the consumer surplus and regression approaches to measuring benefits can be compared across such measures as simplicity of the application in dealing with causality issues (table 9-1). The approaches differ markedly, with each requiring careful application owing to differences in strengths and weaknesses. Generally, the regression approach, which has been used mainly by professional researchers, is better for dealing with causality issues, while the consumer surplus approach, often used by project operations staff, is superior for measuring benefits in monetary terms.

Table 9-1. Comparing strengths and weaknesses of methodological approaches

Methodological Issue	Consumer surplus	Regression
Dealing with causality	*Weak*. Methodology is based on demand for services.	*Strong*. Methodology is based on controlling for other conditions.
Translating benefits into monetary terms	*Strong*. Demand is generally expressed in monetary measures.	*Moderate*. One extra step may be necessary to express results in monetary values (e.g., value of years of education).
Simplicity of application	*Moderate*. Application is fairly simple, but data necessary to define demand curve is not easy.	*Difficult*. Both data collection and analysis techniques are difficult.
Ease of use by project managers	*Moderate*. One-step analysis for services based on demand survey data.	*Difficult*. Two-step analysis predicting outcomes and then applying monetary values.
Danger of double-counting benefits	*High*. Demand for lighting may contain such benefits as improved schooling and increased socializing.	*Low*. Dependent variables are measured and analyzed separately (e.g., years of schooling or time spent socializing).
Can benefits be added together?	*Sometimes*, but caution is needed regarding double-counting benefits (lighting may encourage greater years of schooling).	*Yes*, because generally dependent variables are well-defined (e.g., years of schooling).
Can benefits be added between the consumer surplus and regression approaches?	Generally no, but perhaps if benefits are in a totally different category.	
Necessary data	Consumer survey with variables to measure demand curve in project area for energy intervention.	With-and-without or before-and-after surveys that measure a variety of explanatory and control variables.

Source: This study.

A final question that might be asked is whether the benefits of energy access assessed using the consumer surplus and regression approaches can be added together? The practical answer is no. These two approaches are alternative ways of measuring the same benefits. Under ideal conditions, one method can be used to check for the accuracy of the other. For example, the increased expenditure or income resulting from adopting electricity should be similar to the overall monetary benefits found in using the consumer surplus approach. For estimating the value of consumer surplus, the demand for household lighting has embedded in it a desire to produce more handicrafts or open a small retail store in one room of a home. The income of the impact of electricity on increasing handicrafts production or sales in a store can be measured directly through the regression approach. Therefore, the benefits estimated by the consumer surplus approach and regression approach should, in most cases, be left separate.

Conclusion

Many development agencies today are requiring better monitoring and evaluation (M&E). The reason is that, in the past, investments often plunged ahead into unsuitable areas. The resulting impacts of energy access were limited to a small number of wealthy households. The techniques in this handbook provide the tools for analyzing the benefits of energy access in both monetary and more general terms. These tools can be helpful in directing programs toward areas in which improvements in energy access have the most impact on development. In addition, energy access programs can be coordinated with other development projects and programs to ensure that the right complementary conditions are in place to make the most of modern energy.

Measuring the benefits of energy access is not an easy task. Many of the earlier electrification studies involved simple comparisons of households with and without electricity. The drawback of those approaches was not taking confounding factors into consideration. The earlier methods have since evolved to include both the consumer surplus and regression methods for valuing the benefits of energy access. Along with the evolution of methods for valuing benefits, these methods, by necessity, have become more technical and the surveys more complex and complete. The result has been a better understanding of how energy access impacts development outcomes, which, in turn, has meant a better understanding of the significant monetary benefits of energy access. It turns out that in most cases, the monetary value of the benefits is many times higher than the investment costs. The main conclusion is that the benefits of energy access are worth the investment costs. As a result, many international agencies and efforts, such as Sustainable Energy for All (SEforAll), are calling for increased investments.

Research on the development impact of energy access also contains some cautionary notes. One of the main findings of this research is the complementary conditions that are necessary for programs to have significant impacts on development. Energy programs work better alongside complementary investments in education and health services, water supply, and roads and other infrastructure programs. Household lighting is not much good for increasing children's study hours in the absence of good schools. Refrigeration is not of much use if local markets do not provide fresh vegetables or local produce for sale. To provide entertainment, television requires local broadcasting towers or satellite reception stations. In short, the promotion of energy access must also consider the need for complementary investments.

The trend toward applying better methods and techniques to measuring the benefits of energy access is quite positive. Generally, the findings are that, in most situations, the benefits far outweigh the costs. However, the main relevance of monitoring and evaluating the outcomes of energy access projects are the insights they provide for enhancing the effectiveness of such programs. When it is known that electricity is important for education, then children can be provided with reading materials at home to enhance their performance in class. When clean cooking is known to enhance health and reduce time spent in the kitchen, then measures can be taken to ensure that kitchen appliances are available to further increase the time effectiveness of cooking. Finally, energy access is a necessary but insufficient condition for increasing welfare. The actual benefits of energy access are caused by the use of appliances and such complementary infrastructure programs as roads, schools, and health facilities.

References

Anderson, Dennis. 1975. *Costs and Benefits of Rural Electrification: A Case Study in El Salvador.* World Bank Public Utilities Report No. 5. Washington, DC: World Bank.

Barkat, Abul, M. Rahman, S. Zaman, A. Podder, S. Halim, N. Ratna, M. Majid, A. Maksud, A. Karim, and S. Islam. 2002. "Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh." Report to the National Rural Electric Cooperative Association (NRECA) International. Dhaka: Human Development Research Centre.

Barnes, Douglas. 1988. *Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries*. Boulder, CO: Westview.

———. 2014. *Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries,* Second Edition. Washington, DC: Energy for Development.

Bensch, G., J. Kluve, and J. Peters. 2011. "Impacts of Rural Electrification in Rwanda." *Journal of Development Effectiveness* 3 (4): 567–88.

Bensch, G., M. Grimm, and J. Peters. 2015. "Why Do Households Forego High Returns from Technology Adoption? Evidence from Improved Cooking Stoves in Burkina Faso." *Journal of Economic Behavior & Organization* 116 (2015): 187–205.

Bernard, H. R. 1995. *Research Methods in Anthropology: Qualitative and Quantitative Approaches*. London: AltaMira Press.

Cameron, T. A., and M. D. James. 1986. "Efficient Estimation Methods of 'Closed-Ended' Contingent Valuation Surveys." Working Paper 404. Los Angeles: University of California, Department of Economics.

Chen, Gregory, and Stephen Rasmussen. 2014. *bKash Bangladesh: A Fast Start for Mobile Financial Services*. CGAP Brief. Washington, DC: Consultative Group to Assist the Poor.

Choynowski, Peter. 2002. *Measuring Willingness to Pay for Electricity*. ERD Technical Note 3. Manila: Asian Development Bank.

Cochran, W. 1977. *Sampling Techniques*. New York: John Wiley and Sons.

Cummings, R. G., S. Brookshire, and W. D. Schulze. 1986. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*. Totowa, NJ: Rowman and Allanheld.

Dasgupta, S., P. Martin, and H. Samad. 2015. "Lessons from Rural Madagascar on Improving Air Quality in the Kitchen." *Journal of Environment & Development* 24 (3): 345–69.

Deming, M. E. 1950. *Some Theory of Sampling*. New York: Dover.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101 (7): 3078–108.

Eckholm, Eric. 1975. *The Other Energy Crisis: Firewood*. Washington DC: Worldwatch Institute.

Fernandes, Suneeta D., Nina M. Trautmann, David G. Streets, Christoph A Roden, and Tami C. Bond. 2007. "Global Biofuel Use, 1850–2000." *Global Biogeochemical Cycles* 21 (2): GB2019.

Gertler, Paul J., Sebastian Martinez, Patrick Premand, Laura B. Rawlings, and Christel M. J. Vermeersch. 2011. *Impact Evaluation in Practice*, 37–38. Washington, DC: World Bank Press.

Gonzalez-Eiras, M., and M. Rossi. 2007. "The Impact of Electricity Sector Privatization on Public Health." Inter-American Development Bank, Research Network Initiative, Working Paper #R-524 (http://www.iadb.org/res/pub_desc.cfm?pub_id=r-524).

Grogan, L., and A. Sadanand. 2012. "Rural Electrification and Employment in Poor Countries: Evidence from Nicaragua." *World Development* 43: 252–65.

Gunatilake, H., J. Yang, S. Pattanayak, and C. Berg. 2006. *Willingness-to-Pay and Design of Water Supply and Sanitation Projects: A Case Study*. ERD Technical Note 19. Manila: Asian Development Bank.

Hoevenagel, R. 1994. "An Assessment of the Contingent Valuation." In *Valuing the Environment: Methodological and Measurement Issues*, edited by E. Pething. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Jacobson, Arne, Nicholas L. Lam, Tami C. Bond, and Nathan Hultman. 2013. "Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for Development." Policy Paper 2013-03, Global Economy and Development. Washington, DC: The Brookings Institution.

Jensen, Robert, and Emily Oster. 2007. "The Power of TV: Cable Television and Women's Status in India." Working Paper 13305. Cambridge, MA: National Bureau of Economic Research.

Khandker, Shahidur R. 1996. "Education Achievements and School Efficiency in Rural Bangladesh." World Bank Discussion Paper No. 319. Washington, DC: World Bank.

Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. 2012. "The Welfare Impacts of Rural Electrification in Bangladesh." *Energy Journal* 33 (1): 199–218.

———. 2013. "Welfare Impacts of Rural Electrification: A Panel Data Analysis from Vietnam." *Economic Development and Cultural Change* 61 (3): 659–92.

Khandker, Shahidur R., Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes. 2014. "Who Benefits Most from Rural Electrification? Evidence from India." *Energy Journal* 35 (2): 75–96.

Kish, L. 1965. *Survey Sampling*. New York: John Wiley and Sons.

Kumar, Santosh, and Ganesh Rauniyar. 2011. "Is Electrification Welfare Improving? Non-Experimental Evidence from Rural Bhutan." MPRA Paper 31482. Munich, Germany: University Library of Munich.

la Ferrara, E., A. Chong, and S. Duryea. 2008. "Soap Operas and Fertility: Evidence from Brazil." CEPR Discussion Paper #6785. Washington, DC: Center for Economic and Policy Research.

Lam, Nicholas L., Kirk R. Smith, Alison Gauthier, and Michael N. Bates. 2012a. "Kerosene: A Review of Household Uses and Their Hazards in Low and Middle-Income Countries." *Journal of Toxicology and Environmental Health* 15 (6): 396–432.

Lam, Nicholas L., Yanju Chen, Cheryl Weyant, Chandra Venkataraman, Pankaj Sadavarte, Michael A. Johnson, Kirk R. Smith, Benjamin T. Brem, Joseph Arineitwe, Justin E. Ellis, and Tami C. Bond. 2012b. "Household Light Makes Global Heat: High Black Carbon Emissions from Kerosene Wick Lamps." *Environmental Science & Technology* 46 (24): 13531–38.

Lipscomb, Molly, A. Mushfiq Mobarak, and Tania Barham. 2013. "Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil." *American Economic Journal: Applied Economics* 5 (2): 200-31.

Madigan, F., A. Herrin, and W. Mulcahy. 1976. *Evaluation Study of the MISAMIS Oriental Rural Electric Service Cooperative (MORESCO)*. Report. Washington, DC: United States Agency for International Development.

Meier, Peter, Voravate Tuntivate, Douglas F. Barnes, Susan V. Bogach, and Daniel Farchy. 2010. *Peru: National Survey of Rural Household Energy Use*. Energy and Poverty Special Report, Energy Sector Management Assistance Program (ESMAP). Washington, DC: World Bank.

Mellor, John W. 1976. *The New Economics of Growth.* Ithaca, NY: Cornell University Press.

Mincer, J. 1974. *Schooling, Experience and Earning*. New York: National Bureau of Economic Research, distributed by Columbia University Press.

Mitchel, R. C., and R. T. Carson. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, DC: Resources for the Future.

Modi, V., S. McDade, D. Lallement, and J. Saghir. 2006. *Energy Services for the Millennium Development Goals*. New York: World Bank and United Nations Development Programme.

Monari, L., and D. Mostefai. 2001. "India: Power Supply to Agriculture Summary Report." Energy Sector Unit, South Asia Regional Office. New Delhi: World Bank.

Naeher, L. P., K. R. Smith, B. P. Leaderer, D. Mage, and R. Grajeda. 2000. "Indoor and Outdoor $PM_{2.5}$ and CO in High- and Low-Density Guatemalan Villages." *Journal of Exposure Analysis and Environmental Epidemiology* 10 (5): 544–51.

Nieuwenhout, F., P. Van de Rijt, and E. Wiggelinkhuizen. 1998. *Rural Lighting Services*. Petten: Netherlands Energy Research Foundation.

O'Sullivan, K., and D. Barnes. 2007. "Energy Policies and Multitopic Surveys: Guidelines for Questionnaire Design in Living Standards Measurement Studies." World Bank Working Paper No. 90. Washington, DC: World Bank.

Patrinos, Harry Anthony, Cris Ridao-Cano, and Chris Sakellariou. 2006. "Estimating the Returns to Education: Accounting for Heterogeneity in Ability." Policy Research Working Paper 4040. Washington, DC: World Bank.

Pearce, David, and Michael Webb. 1985. "Economic Benefits of Electricity Supply." Energy Department Paper No. 25. World Bank, Washington D.C.

Peet, Evan D., Gunther Fink, and Wafaie Fawzi. 2015. "Returns to Education in Developing Countries: Evidence from the Living Standards and Measurement Study Surveys." *Economics of Education Review* 49 (December 2015): 69–90.

Pennise, D., S. Brant, S. M. Agbeve, W. Quaye, F. Mengesha, W. Tadele, and T. Wofchuck. 2009. "Indoor Air Quality Impacts of an Improved Wood Stove in Ghana and an Ethanol Stove in Ethiopia." *Energy for Sustainable Development* 13 (2009): 71–76.

Peskin, Henry. 2006. "A Primer on Consumer Surplus and Demand: Common Questions and Answers." ESMAP Knowledge Exchange Series No. 5. World Bank, Washington, DC.

Peters, J., C. Vance, and M. Harsdorff. 2011. "Grid Extension in Rural Benin: Micro-Manufacturers and the Electrification Trap." *World Development* 39 (5): 773–83.

Psacharopoulus, George. 1994. "Returns to Investment in Education: A Global Update." *World Development* 22 (9): 1325–43.

Psacharopoulus, George, and Harry Anthony Patrinos. 2004. "Returns to Investment in Education: A Further Update." *Education Economics* 12 (2): 111–34.

Ramanathan, V., and G. Carmichael. 2008. "Global and Regional Climate Changes Due to Black Carbon." *Nature Geoscience* 1: 221–7.

Range, M., and P. Omondi. 2000. *Chrysalis: Leadership Training for Pioneering Women*. Arlington, VA: Winrock International Institute for Agricultural Development.

Rud, J. P. 2012. "Electricity Provision and Industrial Development: Evidence from India." *Journal of Development Economics* 97 (2): 352–67.

Saunders, J., M. Davis, G. Moses, and J. Ross. 1975. *Rural Electrification and Development: Social and Economic Impact in Costa Rica and Colombia*. Boulder, CO: Westview.

Smith, Kirk. 2000. "National Burden of Disease in India from Indoor Air Pollution." *Proceedings of the National Academy of Sciences* 97 (24): 13286–93.

Smith, K. R., N. Bruce, K. Balakrishnan, H. Adair-Rohani, J. Balmes, and Z. Chafe et al. 2014. "Millions Dead: How Do We Know and What Does It Mean? Methods Used in the Comparative Risk Assessment of Household Air Pollution." *Annual Review of Public Health* 35 (1): 185–206.

Tanguy, Bernard. 2012. "Impact Analysis of Rural Electrification Projects in Sub-Saharan Africa." *World Bank Research Observer* 27 (1): 33–51.

UN Foundation (United Nations Foundation). 2015. "IWG Impact: How Mobile Midwife Is Helping Families in Ghana" (http://unfoundationblog.org/mobile-health-innovation/iwg-impact-how-mobile-midwife-is-helping-families-in-ghana/).

USAID (United States Agency for International Development). 2013. "US Government and Quezon City Partner to Promote Mobile Money Use for Better Governance" (https://www.usaid.gov/philippines/press-releases/us-government-and-quezon-city-partner-promote-mobile-money-use).

———. 2014a. "Mobile Agriculture: A Lifeline for Pakistan's Farmers" (https://blog.usaid.gov/2014/08/mobile-agriculture-a-lifeline-for-pakistans-farmers/).

———. 2014b. "Mobile Persuasion: Can Mobile Phones and Cutting-Edge Behavioral Science Improve Lives?" (https://blog.usaid.gov/2014/04/mobile-persuasion-can-mobile-phones-and-cutting-edge-behavioral-science-improve-lives/).

Venkataraman, C., A. Sagar, G. Habib, and K. Smith. 2010. "The National Initiative for Advanced Biomass Cookstoves: The Benefits of Clean Combustion." *Energy for Sustainable Development* 14 (2): 63–72.

WHO (World Health Organization). 2007. *Indoor Air Pollution: National Burden of Disease Estimates*. Geneva: World Health Organization.

———. 2014. "Household Air Pollution and Health: Fact Sheet" (http://www.who.int/mediacentre/factsheets/fs292/en/).

World Bank. 1999. "Poverty and Social Developments in Peru, 1994–1997." World Bank Country Study. World Bank, Washington, DC.

———. 2002a. *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits.* Energy Sector Management Assistance Program (ESMAP) Report No. 255/02. Washington, DC: World Bank.

———. 2002b. *Energy Strategies for Rural India: Evidence from Six States*. Energy Sector Management Assistance Program (ESMAP) Report No. 258/02. Washington, DC: World Bank.

———. 2003. "Monitoring and Evaluation in Rural Electrification Projects: A Demand-Oriented Approach." Energy Sector Management Assistance Programme (ESMAP). World Bank, Washington, DC.

———. 2008. *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits.* Independent Evaluation Group (IEG) Impact Evaluation. Washington, DC: World Bank.

Yevich, Rosemary, and Jennifer A. Logan. 2003. "An Assessment of Biofuel Use and Burning of Agricultural Waste in the Developing World." *Global Biogeochemical Cycles* 17 (4): 1095.

PART III

Annexes

Annex A. Philippines Household Energy Survey Module

(EGY) ENERGY: FUEL CONSUMPTION

Please indicate which of the following fuels your household has used for any activity during the past 12 months. [0] = No, [1] = Yes

egy1	Fuelwood. If Yes, go to **FW**	egy1	
egy2	Lumber waste. If Yes, go to **LW**	egy2	
egy3	Charcoal. If Yes, go to **CHA**	egy3	
egy4	Kerosene. If Yes, go to **KER**	egy4	
egy5	LPG. If Yes, go to **LPG**	egy5	
egy6	Biomass residue. If Yes, go to **BMR**	egy6	
egy7	Solar energy (for Tingloy Island, Batangas only)	egy7	
egy8	Dry-cell batteries. If Yes, go to **DRY**	egy8	
egy9	Other batteries. If Yes, go to **BAT**	egy9	
egy10	Candles. If Yes, go to **CAN**	egy10	
egy11	Other: Wind energy	egy11	
	Dendrothermal/Geothermal energy If Yes, go to **OTH**		
egy12	Electricity. If Yes, go to **ELE**	egy12	

(FW) FUELWOOD

If household did not use fuelwood, write [-8] in boxes fw1-fw14.

Fw1	Last month, was fuelwood used for the following purposes? [0] No [1] Yes [-1] No response [-8] Not applicable	**fw1**	

Fw1.1	Cooking and boiling water for drinking	**fw1.1**	
Fw1.2	Heating water (for bathing, washing clothes)	**fw1.2**	
Fw1.3	For home business	**fw1.3**	
Fw1.4	Other, specify:	**fw1.4**	
Fw2	How do you obtain your fuelwood? [1] Collect/given only [2] Purchase only [3] Purchase and collect [4] Other, specify: [-1] No response [-8] Not applicable	**fw2**	

The following questions are for purchased fuelwood. If household did not purchase fuelwood, write [-8] in boxes fw3-fw8.

Fw3	What unit(s) of measure do you use in purchasing fuelwood? [1] Bundle [2] Stack or pile [3] Sack or bag [4] Other, specify:	**fw3**	
Fw4	Enumerator: Ask respondent to show you typical stack/bundle/sack. Weigh it and note the weight (in kg). Enter value as the weight of the typical stack/bundle/sack.	**fw4**	
Fw5	During your last purchase, how many units (given in fw4) of fuelwood did you buy?	**fw5**	
Fw6	How much did you spend during your last purchase?	**fw6**	
Fw7	How many total days will this purchase last?	**fw7**	
Fw8	What was the one-way distance traveled (in meters) to make this purchase?	**fw8**	

The following questions are for collected fuelwood. If household did not collect fuelwood, write [-8] in boxes fw9-fw14.

Fw9	What unit(s) of measure do you use in collecting fuelwood? [1] Bundle [2] Stack or pile [3] Sack or bag [4] Other, specify:	**fw9**	
Fw10	Enumerator: Ask respondent to show you typical stack/bundle/sack. Weigh it and note the weight (in kg). Enter value as the weight of the typical stack/bundle/sack.	**fw10**	
Fw11	During last collection, how many units (given in fw10) did you collect?	**fw11**	
Fw12	How much time (hours/week) did members use to collect fuelwood?	**fw12**	
Fw12.1	Adult male	**fw12.1**	
Fw12.2	Adult female	**fw12.2**	
Fw12.3	Children	**fw12.3**	
Fw13	How many total days did this collected fuelwood last?	**fw13**	
Fw14	What was the one-way distance traveled in collecting fuelwood (in meters)?	**fw14**	

(LW) LUMBER WASTE

If household did not use lumber waste, write [-8] in boxes lw1-lw7.

Lw1	Last month, were lumber wastes used for the following purposes? [0] No [1] Yes [-1] No response [-8] Not applicable	**lw1**	
Lw1.1	Cooking and boiling water for drinking	**lw1.1**	
Lw1.2	Heating water (for bathing, washing clothes)	**lw1.2**	
Lw1.3	For home business	**lw1.3**	
Lw1.4	Other, specify:	**lw1.4**	
Lw2	What unit(s) of measure do you use in collecting lumber waste? [1] Bundle [2] Stack or pile [3] Sack or bag [4] Other, specify	**lw2**	

Lw3	Enumerator: Ask respondent to show you typical stack/bundle/ sack. Weigh it and note the weight (in kg). Enter value as the weight of the typical stack/bundle/sack.	**lw3**	
Lw4	During last collection, how many units (given in lw3) did you collect?	**lw4**	
Lw5	How much labor was used in collecting lumber waste?	**lw5**	
Lw5.1	Adult male	**lw5.1**	
Lw5.2	Adult female	**lw5.2**	
Lw5.3	Children	**lw5.3**	
Lw6	How many days did this collected lumber waste last?	**lw6**	
Lw7	What was the one-way distance traveled (in meters) to collect lumber waste?	**lw7**	

(CHA) CHARCOAL

If household did not use charcoal, write [-8] in boxes cha1-cha7.

cha1	Last month, was charcoal used for the following purposes? [0] No [1] Yes [-1] No response [-8] Not applicable	**cha1**	
cha1.1	Cooking and boiling water for drinking	**cha1.1**	
cha1.2	Heating water (for bathing, washing clothes)	**cha1.2**	
cha1.3	Ironing	**cha1.3**	
cha1.4	For home business	**cha1.4**	
cha1.5	Other, specify:	**cha1.5**	
cha2	What unit(s) of measure do you use in purchasing charcoal? [1] Bundle [2] Stack or pile [3] Sack [4] Other, specify:	**cha2**	
cha3	Enumerator: Ask respondent to show you typical stack/bundle/sack. weigh it and note the weight (in kg). Enter value as the weight of the typical stack/bundle/sack.	**cha3**	
cha4	During your last purchase, how many units (given in cha3) of charcoal did you buy?	**cha4**	
cha5	How much did you spend during your last purchase?	**cha5**	

cha6	How many total days will this purchase last?	**cha6**	
cha7	What was the one-way distance traveled (in meters) to make this purchase?	**cha7**	
cha8	Do you produce your own charcoal? [0] No. If No, go to KER. [1] Yes	**cha8**	
cha9	During the last production, how many units (given in cha3) did you produce?	**cha9**	
cha10	How much did you spend to produce this charcoal?	**cha10**	
cha11	How many total days did this own-produced charcoal last?	**cha11**	
cha12	What proportion of the charcoal that you produced did you consume?	**cha12**	
cha13	What proportion of the charcoal that you produced did you sell?	**cha13**	
cha14	At what average price did you sell this own-produced charcoal?	**cha14**	

(KER) KEROSENE

If household did not use kerosene, write [-8] in boxes ker1-ker5.

ker1	Last month, was kerosene used for the following purposes? [0] No [1] Yes [-1] No response [-8] Not applicable	**ker1**	
ker1.1	Cooking and boiling water for drinking	**ker1.1**	
ker1.2	Heating water (for bathing, washing clothes)	**ker1.2**	
ker1.3	Lighting	**ker1.3**	
ker1.4	For home business	**ker1.4**	
ker1.5	Other, specify:	**ker1.5**	
ker2	During your last purchase, how many liters of kerosene did you buy?	**ker2**	
ker3	How much did you spend during your last purchase?	**ker3**	
ker4	How many total days will this purchase last?	**ker4**	
ker5	What was the one-way distance traveled (in meters) to make this purchase?	**ker5**	

(LPG) LPG

If household did not use LPG, write [-8] in boxes lpg1-lpg6.

lpg1	Last month, was LPG used for the following purposes? [0] No [1] Yes [-1] No response [-8] Not applicable	**lpg1**	
lpg1.1	Cooking and boiling water for drinking	**lpg1.1**	
lpg1.2	Heating water (for bathing, washing clothes)	**lpg1.2**	
lpg1.3	Lighting	**lpg1.3**	
lpg1.4	For home business	**lpg1.4**	
lpg1.5	Other, specify:	**lpg1.5**	
lpg2	What size of LPG tank does your household usually use? [1] 7 kg [2] 11 kg [3] Other, specify:	**lpg2**	
lpg3	How many LPG tanks do you have?	**lpg3**	
lpg4	How much did you spend during your last purchase?	**lpg4**	
lpg5	How many total days will this purchase last?	**lpg5**	
lpg6	What was the one-way distance traveled (in meters) to make this purchase?	**lpg6**	

(BMR) BIOMASS RESIDUE

If household did not use biomass residue, write [-8] in boxes bmr1-bmr7.

bmr1	Last month, was biomass residue used for the following purposes? [0] No [1] Yes [-1] No response [-8] Not applicable	**bmr1**	
bmr1.1	Cooking and boiling water for drinking	**bmr1.1**	
bmr1.2	Heating water (for bathing, washing clothes)	**bmr1.2**	
bmr1.3	Ironing	**bmr1.3**	

bmr1.4	Home business	**bmr1.4**	
bmr1.5	Other, specify:	**bmr1.5**	
bmr2	What unit(s) of measure do you use in collecting biomass residue? [1] Bundle [2] Stack or pile [3] Sack or bag [4] Other, specify:	**bmr2**	
bmr3	Enumerator: Ask respondent to show you typical stack/bundle/sack. Weigh it and note the weight (in kg). Enter value as the weight of the typical stack/bundle/sack.	**bmr3**	
bmr4	During last collection, how many units (given in bmr2) did you collect?	**bmr4**	
bmr5	How much total time did following members use to collect biomass residue?	**bmr5**	
bmr5.1	Adult male	**bmr5.1**	
bmr5.2	Adult female	**bmr5.2**	
bmr5.3	Children	**bmr5.3**	
bmr6	How many total days did this collected biomass residue last?	**bmr6**	
bmr7	What was the one-way distance traveled (in meters) to collect Biomass residue?	**bmr7**	

(SOL) SOLAR ENERGY

sol1	Does your household own any small solar PV system? [0] No [1] Yes. If Yes, go to sol6.	**sol1**	
sol2	Have you heard about this small size solar PV system? [0] No [1] Yes, from newspaper or magazine. [2] Yes, from radio or TV. [3] Yes, from neighbors and friends. [4] Yes, saw it in store. [5] Yes, saw a system installed at friend's, government's, or neighbor's [6] Yes, other source, specify:	**sol2**	
sol3	Are you interested in buying such a small solar PV system with cash? [0] No [1] Yes [2] Never heard of it/Don't know	**sol3**	

sol4	Are you interested in buying this small solar PV system with down payment and credit? [0] No [1] Yes [2] Never heard of it/Don't know	**sol4**	
sol5	What are your main and secondary reasons for not purchasing? [0] No reason [1] Main reason [2] Secondary reason	**sol5**	
sol5.1	System costs too much	**sol5.1**	
sol5.2	No convenient location to buy	**sol5.2**	
sol5.3	Do not want to buy	**sol5.3**	
sol5.4	Do not know about the system	**sol5.4**	
sol5.5	Cannot get credit to buy system	**sol5.5**	

The next section is for solar PV system owners only. If household does not have solar PV system, write [-8] in boxes sol6-sol34.

sol6	How many solar PV systems does your household have?	**sol6**	
sol7	What do you think about the price of your solar PV system? [1] Very expensive [2] Expensive [3] Right price [4] Cheap	**sol7**	
	I will ask you about the size of each solar PV system that you have. If you only have one system, answer only the first system; if you have two systems, first and second systems etc. (Fill in 20 if the system is 50 watts peak (Wp); if the system is 75 Wp, fill in 30; interviewer must ask and check for the correct size.)		
sol8	What is the size (in Wp) of your first solar PV system?	**sol8**	
sol9	How long (in months) has it been since your household had your first solar PV system installed?	**sol9**	
sol10	How much did you pay (in Pesos) for the up-front costs of the first system? (If paid in full, fill in "full payment" and go to sol13)	**sol10**	
sol11	How much (in Pesos) is the monthly installment payment?	**sol11**	
sol12	For how many months?	**sol12**	
sol13	What is the size (in Wp) of your second solar PV system?	**sol13**	

sol14	How long (in months) has it been since your household had your second solar PV system installed?	**sol14**	
sol15	How much did you pay (in Pesos) for the up-front costs of the second system? (If paid in full, fill in "full payment" and go to sol18)	**sol15**	
sol16	How much (in Pesos) is the monthly installment payment?	**sol16**	
sol17	For how many months?	**sol17**	
sol18	What is the size (in Wp) of your third solar PV system?	**sol18**	
sol19	How long (in months) has it been since your household had your third solar PV system installed?	**sol19**	
sol20	How much did you pay (in Pesos) for the up-front costs of the third system? (If paid in full, fill in "full payment" and go to sol23)	**sol20**	
sol21	How much (in Pesos) is the monthly installment payment?	**sol21**	
sol22	For how many months?	**sol22**	
sol23	How many times has your solar PV system broken down since you bought it?	**sol23**	
sol24	Do you have to change any of your solar PV panels? [0] No [1] Yes [-8] Not applicable	**sol24**	
sol25	When the system has broken down, which of the following parts have broken down? [0] No [1] Yes [-8] Not applicable	**sol25**	
sol25.1	Battery	**sol25.1**	
sol25.2	Lamp (light bulb/tube)	**sol25.2**	
sol25.3	Battery control unit	**sol25.3**	
sol25.4	Solar panel	**sol25.4**	
sol25.5	Inverter	**sol25.5**	
sol25.6	Wiring	**sol25.6**	
sol26	What is the average cost of repair?	**sol26**	
sol27	How long (in months) has your last battery lasted?	**sol27**	
sol28	How long (in months) has your light bulb/tube lasted?	**sol28**	
sol29	Last year, what was the total number of days your solar PV system was out of order?	**sol29**	

sol30	Why does your household have to live without electricity from solar PV system for that many days? [0] No [1] Yes	**sol30**	
sol30.1	Normal waiting time for repair when it is out of service	**sol30.1**	
sol30.2	Difficult to find spare parts	**sol30.2**	
sol30.3	Could not find any repair person or repair person is not available	**sol30.3**	
sol30.4	Repair is too costly	**sol30.4**	
sol30.5	Have to travel long distance to repair or buy part	**sol30.5**	
sol30.6	System is under warranty and service provided is slow	**sol30.6**	
sol30.7	Other, specify:	**sol30.7**	
sol31	If solar PV system breaks down, how do you have it repaired? [1] Technician/repair person comes to our house to repair. Go to DRY. [2] Take it to repair shop. Go to sol32 [3] Other, specify: Go to DRY.	**sol31**	
sol32	Means of transportation [1] Bicycle [2] Motorcycle [3] Bus/truck [4] Horse [5] Cart [6] Other, specify:	**sol32**	
sol33	Distance to repair shop (in kilometers)	**sol33**	
sol34	What is the total transportation cost (to and from) for each repair?	**sol34**	

(DRY) DRY-CELL BATTERIES

If household did not use dry-cell batteries, write [-8] in boxes dry1-dry5.

dry1	What do you use drycell batteries for? [0] No [1] Yes [-1] No response [-8] Not applicable	**dry1**	
dry1.1	Radio/cassette player	**dry1.1**	
dry1.2	Electric fan	**dry1.2**	

dry1.3	Lighting	dry1.3	
dry1.4	Clock	dry1.4	
dry1.5	Toys	dry1.5	
dry1.6	Television	dry1.6	
dry1.7	Flashlight	dry1.7	
dry1.8	Other, specify:	dry1.8	
dry2	How many times per month do you usually purchase dry-cell batteries?	dry2	
dry3	During your last purchase, how many batteries did you buy?	dry3	
dry4	How much did you spend during your last purchase?	dry4	
dry5	What was the one-way distance traveled (in meters) to make this purchase?	dry5	

(BAT) OTHER BATTERIES – VEHICULAR

If household did not use vehicular batteries, write [-8] in boxes bat1-bat9.

bat1	Do you use vehicular batteries for: [0] No [1] Yes [-1] No response [-8] Not applicable	bat1	
bat1.1	Radio/cassette player	bat1.1	
bat1.2	Electric fan	bat1.2	
bat1.3	Lighting	bat1.3	
bat1.4	Television	bat1.4	
bat1.5	Other, specify:	bat1.5	
bat2	How much is the acquisition cost of the battery (Pesos)?	bat2	
bat3	How many years do you expect the battery to last?	bat3	
bat4	How often do you charge the battery per month?	bat4	
bat5	What is the primary charging source? [1] Power line [2] Cooperative [3] Commercial source [4] Other, specify:	bat5	
bat6	How many days does one charge last?	bat6	
bat7	How many hours per day do you use the battery?	bat7	
bat8	What was the one-way distance traveled (in meters) to have the battery recharged?	bat8	
bat9	What is the average round-trip cost of transportation to the recharge station?	bat9	

(CAN) CANDLES

If household did not use candles, write [-8] in boxes can1 to can5.

can1	What do you use candles for? [0] No [1] Yes [-1] No response [-8] Not applicable	**can1**	
can1.1	Lighting	**can1.1**	
can1.2	Religious rites	**can1.2**	
can1.3	Other, specify:	**can1.3**	
can2	How many candles do you use per month?	**can2**	
can3	For your last purchase, how many sticks of candles did you buy?	**can3**	
can4	How much did this purchase cost?	**can4**	
can5	How many days did this purchase last?	**can5**	

(OTH) OTHER

If household did not use other types of energy, write [-8] in boxes oth1-oth4.

oth1	What other type of energy source do you use? [1] Water [2] Dendrothermal/Geothermal	**oth1**	
oth2	For what purpose do you use this type of fuel? [0] No [1] Yes [-1] No response [-8] Not applicable	**oth2**	
oth2.1	Cooking and boiling water for drinking	**oth2.1**	
oth2.2	Heating water (for bathing, washing clothes)	**oth2.2**	
oth2.3	Ironing	**oth2.3**	
oth2.4	Home business	**oth2.4**	
oth2.5	Other, specify:	**oth2.5**	
oth3	How many times per month do you usually purchase this type of energy?	**oth3**	
oth4	How much does it cost you per month to use this type of energy?	**oth4**	

(ELE) ELECTRICITY

If household is not electrified, write [-8] in boxes ele1-ele26.4

ele1	How many years has your household used electricity?	**ele1**	
ele2	What type of service do you have? [1] 24-hour service [2] 12-hour service [3] Other, specify:	**ele2**	
ele3	Do you share your electric appliances with people outside your household? [0] No. If No, go to ele5. [1] Yes	**ele3**	
ele4	Which electric appliance is shared with people outside your household? [0] No [1] Yes	**ele4**	
ele4.1	Refrigerator	**ele4.1**	
ele4.2	Television	**ele4.2**	
ele4.3	Electric iron	**ele4.3**	
ele4.4	Cooking appliance	**ele4.4**	
ele4.5	Washing machine	**ele4.5**	
ele4.6	Other, specify:	**ele4.6**	
ele5	To whom do you pay the electric charges/bill? [0] None (no meter or illegal connection). If None, go to **ele11**. [1] Electric cooperative [2] Electric company other than cooperative [3] Landlord [4] Neighbor [5] Other, specify:	**ele5**	
ele6	How often are you supposed to pay? [1] Twice a month [2] Monthly [3] Every other month [4] Other, specify:	**ele6**	
ele7	Can you provide the following information from your latest electric bill?	**ele7**	
ele7.1	Total days for last electric bill	**ele7.1**	
ele7.2	Total charges for last bill	**ele7.2**	
ele7.3	Total kilowatt hours consumed for last bill	**ele7.3**	

ele8	How many households are sharing the electricity bill?	**ele8**	
ele9	If tapped to neighbor, how much do you pay per month?	**ele9**	
ele10	How is this rate determined if electricity is tapped from neighbor? [1] Number of appliance [2] Incremental meter use [3] Do not know [-8] Not applicable	**ele10**	
ele11	How many times did the power fail for more than 30 minutes last month?	**ele11**	
ele12	How often did the power trip for more than 30 seconds last month? [1] Often [2] Rarely [3] Never	**ele12**	
ele13	How often did you experience dimming of lights last month? [1] Often [2] Rarely [3] Never	**ele13**	
ele14	What do you miss most when there is a brownout? [1] Lighting [2] Watching TV [3] Listening to radio/music [4] Attending social gatherings [5] Sewing/cooking [6] Using fan/cooling appliance [7] Using refrigerator [8] Reading, studying [9] Other, specify:	**ele14**	
ele15	What is the second thing you miss most when there is a brownout? [1] Lighting [2] Watching TV [3] Listening to radio/music [4] Attending social gatherings [5] Sewing/cooking [6] Using fan/cooling appliance [7] Using refrigerator [8] Reading, studying [9] Other, specify:	**ele15**	

The next section is about emergency lighting.

ele16	What do you use for lighting when there is no electricity? [0] No [1] Yes	**ele16**	
ele16.1	Generator. If Yes, go to **ele17**.	**ele16.1**	
ele16.2	Emergency light/rechargeable lamps. If Yes, go to **ele18**.	**ele16.2**	
ele16.3	Kerosene lamp. If Yes, go to **ele19**.	**ele16.3**	
ele16.4	LPG appliance. If Yes, go to **ele20**.	**ele16.4**	
ele16.5	Vehicular battery. If Yes, go to **ele21**.	**ele16.5**	
ele16.6	Candles. If Yes, go to **ele22**.	**ele16.6**	
ele16.7	Flashlight and dry-cell lamp. If Yes, go to **ele23**.	**ele16.7**	
ele16.8	Other, specify: If Yes, go to **ele24**.	**ele16.8**	
ele17	Generator	**ele17**	
ele17.1	Power generation capacity in kilowatt hours	**ele17.1**	
ele17.2	How many years have you been using a generator?	**ele17.2**	
ele17.3	Acquisition cost of generator	**ele17.3**	
ele17.4	Type of fuel used: [1] Gasoline [2] Diesel	**ele17.4**	
ele17.5	Monthly expenditure on fuel	**ele17.5**	
ele18	Emergency light/rechargeable lamps	**ele18**	
ele18.1	Total acquisition cost of emergency lights/lamps	**ele18.1**	
ele18.2	Expenditures incurred per month (bulb and charging)	**ele18.2**	
ele19	Kerosene lamp	**ele19**	
ele19.1	Total acquisition cost of kerosene lamp	**ele19.1**	
ele19.2	Expenditures incurred per month	**ele19.2**	
ele19.3	Liters of kerosene used per month	**ele19.3**	
ele20	LPG appliance	**ele20**	
ele20.1	Total acquisition cost of LPG appliance	**ele20.1**	
ele20.2	Expenditures incurred per month	**ele20.2**	
ele20.3	kg of LPG used per month	**ele20.3**	
ele21	Vehicular battery	**ele21**	
ele21.1	Total cost of vehicular batteries	**ele21.1**	
ele21.2	Expenditures incurred per month (e.g. charging)	**ele21.2**	
ele22	Candle	**ele22**	

ele22.1	Expenditures incurred per month	**ele22.1**	
ele23	Flashlight and drycell lamp	**ele23**	
ele23.1	Total acquisition cost of flashlight/drycell lamp	**ele23.1**	
ele23.2	Expenditures incurred per month	**ele23.2**	
ele24	Other energy source	**ele24**	
ele24.1	Total cost of other energy source	**ele24.1**	
ele24.2	Expenditures incurred per month	**ele24.2**	

The next section is about electricity used in home business. If household does not have a home business, write [-8] in boxes ele25-ele26.4.

ele25	Do you use electricity in your home business? [0] No. If No, go to **INC** [1] Yes [-8] Do not have home business; go to **INC**	**ele25**	
ele26	What do you use electricity for in your home business? [0] No [1] Yes [-1] No response [-8] Not applicable	**ele26**	
ele26.1	Lighting	**ele26.1**	
ele26.2	Refrigeration and cold storage	**ele26.2**	
ele26.3	Food processing	**ele26.3**	
ele26.4	Other, specify:	**ele26.4**	

(INC) INCANDESCENT BULBS
(only bulbs used for more than 30 minutes per day)

inc1	25 W	**inc1**	
inc1.1	Number of bulbs	**inc1.1**	
inc1.2	Total hours used per day	**inc1.2**	
inc2	40 W	**inc2**	
inc2.1	Number of bulbs	**inc2.1**	
inc2.2	Total hours used per day	**inc2.2**	
inc3	50 W	**inc3**	
inc3.1	Number of bulbs	**inc3.1**	
inc3.2	Total hours used per day	**inc3.2**	
inc4	60 W	**inc4**	
inc4.1	Number of bulbs	**inc4.1**	

inc4.2	Total hours used per day	**inc4.2**	
inc5	100 W	**inc5**	
inc5.1	Number of bulbs	**inc5.1**	
inc5.2	Total hours used per day	**inc5.2**	

(TUB) FLUORESCENT TUBES–STRAIGHT AND CIRCULAR
(only tubes used for more than 30 minutes per day)

tub1	10 W straight	**tub1**	
tub1.1	Number of tubes	**tub1.1**	
tub1.2	Total hours used per day	**tub1.2**	
tub2	20 W straight	**tub2**	
tub2.1	Number of tubes	**tub2.1**	
tub2.2	Total hours used per day	**tub2.2**	
tub3	40 W straight	**tub3**	
tub3.1	Number of tubes	**tub3.1**	
tub3.2	Total hours used per day	**tub3.2**	
tub4	22 W circular	**tub4**	
tub4.1	Number of tubes	**tub4.1**	
tub4.2	Total hours used per day	**tub4.2**	
tub5	32 W circular	**tub5**	
tub5.1	Number of tubes	**tub5.1**	
tub5.2	Total hours used per day	**tub5.2**	

(COM) compact fluorescent tubes SL
(only tubes used for more than 30 minutes per day)

com1	Less than 12 W	**com1**	
com1.1	Number of tubes	**com1.1**	
com1.2	Total hours used per day	**com1.2**	
com2	12 W	**com2**	
com2.1	Number of tubes	**com2.1**	
com2.2	Total hours used per day	**com2.2**	
com3	18 W	**com3**	
com3.1	Number of tubes	**com3.1**	
com3.2	Total hours used per day	**com3.2**	

com4	20 W	**com4**	
com4.1	Number of tubes	**com4.1**	
com4.2	Total hours used per day	**com4.2**	
com5	25 W	**com5**	
com5.1	Number of tubes	**com5.1**	
com5.2	Total hours used per day	**com5.2**	

(NEA) NON-ELECTRIC APPLIANCES

Do you have/use any of the following at home?

nea1	Clay stove/efficient stove using fuelwood	**nea1**	
nea1.1	Number	**nea1.1**	
nea1.2	Hours used per day	**nea1.2**	
nea2	Traditional/improvised clay stove using fuelwood	**nea2**	
nea2.1	Number	**nea2.1**	
nea2.2	Hours used per day	**nea2.2**	
nea3	Kerosene stove	**nea3**	
nea3.1	Number	**nea3.1**	
nea3.2	Hours used per day	**nea3.2**	
nea4	Charcoal stove	**nea4**	
nea4.1	Number	**nea4.1**	
nea4.2	Hours used per day	**nea4.2**	
nea5	Biomass residue stove	**nea5**	
nea5.1	Number	**nea5.1**	
nea5.2	Hours used per day	**nea5.2**	
nea6	Kerosene lamps	**nea6**	
nea6.1	Number	**nea6.1**	
nea6.2	Hours used per day	**nea6.2**	
nea7	Candle lamps	**nea7**	
nea7.1	Number	**nea7.1**	
nea7.2	Hours used per day	**nea7.2**	
nea8	Charcoal flat iron	**nea8**	
nea8.1	Number	**nea8.1**	
nea8.2	Hours used per day	**nea8.2**	

(EA) ELECTRIC APPLIANCES

Do you have/use any of the following at home?

ea1	Radio	**ea1**	
ea1.1	Number	**ea1.1**	
ea1.2	Total watts	**ea1.2**	
ea1.3	Hours used per day	**ea1.3**	
ea2	Black-and-white TV	**ea2**	
ea2.1	Number	**ea2.1**	
ea2.2	Total watts	**ea2.2**	
ea2.3	Hours used per day	**ea2.3**	
ea3	Color TV	**ea3**	
ea3.1	Number	**ea3.1**	
ea3.2	Total watts	**ea3.2**	
ea3.3	Hours used per day	**ea3.3**	
ea4	Electric flat iron	**ea4**	
ea4.1	Number	**ea4.1**	
ea4.2	Total watts	**ea4.2**	
ea4.3	Hours used per week	**ea4.3**	
ea5	Electric fan	**ea5**	
ea5.1	Number	**ea5.1**	
ea5.2	Total watts	**ea5.2**	
ea5.3	Hours used per day	**ea5.3**	
ea6	Water heater	**ea6**	
ea6.1	Number	**ea6.1**	
ea6.2	Total watts	**ea6.2**	
ea6.3	Hours used per day	**ea6.3**	
ea7	Refrigerator	**ea7**	
ea7.1	Number	**ea7.1**	
ea7.2	Total watts	**ea7.2**	
ea7.3	Hours used per day	**ea7.3**	
ea8	Electric stove/burner	**ea8**	
ea8.1	Number	**ea8.1**	
ea8.2	Total watts	**ea8.2**	

ea8.3	Hours used per day	**ea8.3**	
ea9	Toaster/turbo broiler	**ea9**	
ea9.1	Number	**ea9.1**	
ea9.2	Total watts	**ea9.2**	
ea9.3	Hours used per day	**ea9.3**	
ea10	Electric oven/range	**ea10**	
ea10.1	Number	**ea10.1**	
ea10.2	Total watts	**ea10.2**	
ea10.3	Hours used per day	**ea10.3**	
ea11	Washing machine	**ea11**	
ea11.1	Number	**ea11.1**	
ea11.2	Total watts	**ea11.2**	
ea11.3	Hours used per week	**ea11.3**	
ea12	Electric water pump	**ea12**	
ea12.1	Number	**ea12.1**	
ea12.2	Total watts	**ea12.2**	
ea12.3	Hours used per day	**ea12.3**	
ea13	Power tools (e.g., power drills)	**ea13**	
ea13.1	Number	**ea13.1**	
ea13.2	Total watts	**ea13.2**	
ea13.3	Hours used per day	**ea13.3**	
ea14	Generator	**ea14**	
ea14.1	Number	**ea14.1**	
ea14.2	Total watts	**ea14.2**	
ea14.3	Hours used per day	**ea14.3**	
ea15	Other, specify:	**ea15**	
ea15.1	Number	**ea15.1**	
ea15.2	Total watts	**ea15.2**	
ea15.3	Hours used per day	**ea15.3**	

Annex B. Peru Household Energy Survey Questionnaire

300. SOURCES OF ENERGY (Only for the head of home or the spouse)

	301. Are the following energy sources used in your home?	YES	NO
1	Electricity from interconnected grid or isolated system	1	2
2	Kerosene	1	2
3	Candles	1	2
4	Dry-Cell Batteries	1	2
5	Car Batteries	1	2
6	LPG	1	2
7	Solar PV Home System	1	2
8	Firewood	1	2
9	Animal Dung	1	2
10-	Crop Residue	1	2
11	Electric Generator Set	1	2
12	Charcoal	1	2
13	Coal	1	2
14	Other, specify	1	2

SECTION 1. USE OF ELECTRICITY FROM INTER CONNECTED GRID AND ISOLATED SYSTEM

302. Does your home have an electricity connection?	
Yes 1	*GO TO 304*
No 2	*GO TO 303A*

303A. If your home has no electricity, please indicate whether the following statements are major, minor, or not a reason to explain why the household is not connected to the grid.

Code: Major Reason = 1
Minor Reason = 2
Not a Reason = 3
Not Applicable = –7

	Major Reason	Minor Reason	Not a Reason
1. Electricity is not available in my area			
2. Our household can't pay the connection fee			
3. Our household can't pay the cost of house wiring			
4. Our household can't afford the monthly payment			
5. Our household can't afford to buy electrical equipment			
6. We are satisfied with present energy source			
7. We do not see any application of electricity			
8. Other reason______________________			

303B. If your home has no electricity, would you like to have access to grid electricity?	
Yes 1	*GO TO 326*
No 2	*GO TO 326*

304. What is the name of the distribution company that provides electricity service in your home?

Code: Write down name of the company

____

305. In what year was the electrical connection first made to your home?

Code: Year of connection of home (e.g., 1958)
Does not know -8

306. Does your home have an electric meter?

Yes 1
No 2 GO TO 308

307. How many households are connected to the same electric meter including yours?

Code: Number of homes

or "1" if the responding household is the only home that connects to electric meter

308. HOW MANY HOURS PER DAY DOES YOUR HOME TYPICALLY HAVE ELECTRICITY SERVICE?	**309.** HOW MANY DAYS PER MONTH DOES YOUR HOUSEHOLD TYPICALLY HAVE ELECTRICITY SERVICE IN YOUR HOME?	**310.** DURING THE LAST 12 MONTHS, HOW MANY MONTHS HAS YOUR HOME HAD ELECTRICITY SERVICE?
Code: Hours per day of service Don't know -8	Code: Days per month of service Don't know -8	Code: Months with service for the last 12 months Don't know -8

311. TO WHOM DOES YOUR HOUSEHOLD PAY FOR THE ELECTRICITY SERVICE THAT YOU RECEIVE AT HOME?

Directly to the distributing company…1
Pay to the neighbor or relative.…2
The electricity is included in the rent…3 GO TO 315A
Others ____________________4
(Specify)
Do not pay…………………………….5 GO TO 315A

312. How does your household pay for the electrical service that you receive in your home?

Per kWh used 1
(Amount of units consumed shown in the Meter)
By the number of bulbs, fluorescent tubes, or electrical apparatuses 2
Fixed charge or Flat rate 3

Others 4
(Specify)

How much does household pay for each billing per billing?	No. of days per period

GO TO 315A

313. If household pays the distributing company directly, request to see the last 3 bills.
Enumerator: Fill in the information below by reading from the bill. Enter "-7" for Not applicable
Only record kWh usage and cost of electricity excluding installation fee.
Do not include installation fee that may be included in the bill.

	Date of the previous reading			**Date of the last reading**			**G. kWh Usage**	**H. Cost (S/.)**
	A. Day	**B. Month**	**C. Year**	**D. Day**	**E. Month**	**F.Year**		
Bill # 1								
Bill# 2								
Bill# 3								

314A. If respondent cannot show previous electricity bill, what is the average payment for one month (30 days) of electric service?

Code: Enter payment in S/per month
Does not know -8

314B. Does the amount of payment mentioned in 314A include installation fee?

Code:
Does not know -8

Yes 1 Enter amount in S/.
No 2 (monthly)
Does not know -8

	315A. Does your household use any of the following INCANDESCENT LIGHT BULBS?			**315B. How many light bulbs of this class do the household use?**	**315C. What is the sum of all hours for all bulbs used during the last 24-hour period** Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
N	Type and size of light bulb	Yes	No	No. of Incandescent	No. of Hours	No. of Minutes
1	25 Watts	1	2			
3	50 Watts	1	2			
4	75Watts	1	2			
5	100 Watts	1	2			

	316A. Does your household use any of the following FLUORESCENT TUBES?			**316B. How many tubes of this class does the household use?**	**316C. What is the sum of all hours for all bulbs used during the last 24-hour period** Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
N	Type and size of light fluorescent	Yes	No	No. of Fluorescent	No. of Hours	No. of Minutes
1	10 W (Straight)	1	2			
2	20 W (Straight)	1	2			
3	40 W (Straight)	1	2			
4	22 W (Circular)	1	2			
5	32 W (Circular)	1	2			

	317A. Does your household use any of the following ENERGY SAVING LIGHT BULBS?			**317B. How many tubes of this class does the household use?**	**317C. What is the sum of all hours for all bulbs used during the last 24-hour period** Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
				Code: Enter the number, or "-7" for do not use	Code: Enter "-7" for do not use	
N	Type and size of energy saving light bulb	Yes	No	No. of energy saving light bulbs	No. of Hours	No. of Minutes
1	< 12 Watts	1	2			
2	12 Watts	1	2			
3	18 Watts	1	2			
4	20 Watts	1	2			
5	25 Watts	1	2			

318A. Does your household use electricity for the following purposes?			**318B. In general, what percentage of spending on electricity each month is for the following purposes?**	
Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
Use type	Yes	No	Percentage	Does not know
1. Lighting	1	2		-8
2. Cooking	1	2		-8
3. Electric Appliances	1	2		-8
4. Family Business	1	2		-8
5. Farm Irrigation	1	2		-8
6. Other	1	2		-8
Total			100%	

319A. Does your household use the following plug-in electric appliances?				319B. How many of each appliance does the household use?	319C. What is the average wattage rating of the appliance? Note: Estimate the average wattage if more than one appliance in use.	319D. What is the sum of all hours for all appliances used during the last 24-hour period? Note to enumerators: If the household has more than one appliance of this type, ask the respondent about the use of each appliance in the household and sum the total hours that the appliances are used in the last 24 hours.	
	Appliance Type	Y	N	Code: Enter the number or "-7" for do not use	Code: Enter the average number of watts of appliances or "-7" for do not use	Code: Enter hours of use with fraction., or "-7" for do not use No. of Hours	No. of Minutes
1	Radio	1	2				
2	Sound equipment	1	2				
3	TV Black and White	1	2				
4	TV color	1	2				
5	Recording video/DVD?	1	2				
6	Electric motors	1	2				
7	Refrigerator	1	2				
8	Microwave oven	1	2				
9	Electric stove	1	2				
10	Electric Iron	1	2				
11	Fan	1	2				
12	Washing machine	1	2				
13	Domestic water pump	1	2				
14	Electrical sewer machine	1	2				
15	Electric drill	1	2				
16	Electric saw	1	2				
17	Electric pump for irrigation	1	2				
18	Others? (Specify)	1	2				
19	Others? (Specify)	1	2				
20	Others? (Specify)	1	2				

320A. In your opinion, your household electricity supply during the dry season is:

Normal	1
Irregular	2
Not applicable	-7

320B. In your opinion, your household electricity supply during the rainy season is:

Normal	1
Irregular	2
Not applicable	-7

321. Over the past month, how many times has the household's electricity services failed for more than 30 minutes?

Code:	Number of times		
	Never	0	GO TO 323
	Does not know	–8	

322. Over the past one month, could you please estimate the amount of hours (in total) electricity service that has not been available to your home due to electricity cuts or blackouts?

Code:	Enter hours with fraction	
	Does not know	–8

323. Over the past one month, how often did the household experience dimming of the light?

Often	*1*
Rarely	*2*
Never	*3*

324. In case of power failure, what is the backup equipment does the household use if any?		
	Yes	No
A. Candles	1	2
B. Kerosene Wick Lamp	1	2
C. Petromax	1	2
D. Gas Lamp	1	2
E. Car/Motorcycle Battery	1	2
F. Generator	1	2

325. Please indicate whether the following are major, minor or not reasons for your household connecting to grid electricity?			
Code: Major Reason = 1 Minor Reason = 2 No Reason = 3			
	Major Reason	Minor Reason	No Reason
1. For entertainment	1	2	3
2. For information and/or the news	1	2	3
3. For better lighting within the home	1	2	3
4. For better safety outside the home	1	2	3
5. To improve income	1	2	3
6. Because electricity is cheaper than other fuels	1	2	3
7. For education of your children	1	2	3
8. Other reason________________________	1	2	3

SECTION 2. USE OF KEROSENE

326. In the past month did your household use kerosene?	
Yes 1	
No 2	GO TO 330

327A. How does your household usually purchase kerosene?	327B. How many units of kerosene do you use per month? Note: Unit refers to type of measurement answered in A. Use decimal point for less than one gallon or liter.	327D. What is the price of each unit of kerosene?	327E. What is the average monthly expenditure on kerosene?
Code: 1 = Gallons 2 = Liters 3 = Other, specify ______	Code: Enter number of units of kerosene used in a month.	Code: Enter price in S/. per unit answered in A.	Code: Amount in S/. of monthly spending.
Code Number	Quantity	S/. per uint	S/. per month

328A. Does your household use kerosene for the following purposes?			328B. In general, what percentage of kerosene does the household use each month for the following purposes?	
Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
	Yes	No	Percent	Does Not Know
1. To Start Firewood	1	2		-8
2. Lamp lighting	1	2		-8
3. Cooking	1	2		-8
4. Appliances	1	2		-8
5. Home Business	1	2		-8
6. Other, specify	1	2		-8
Total			100%	

329A. Does your household use any of the following lamps or appliances?			329B. How many of each of these appliances does your household use?	329C. What is the sum of all hours for all … used during the last 24-hour period? Note: Ask the respondent about the use of each … in the household and sum the total hours that the ... are used in the last 24 hours.	329D. What is the sum of all days for all … used during the last month? Note: Ask the respondent about the use of each …in the household and sum the total days that the…are used in the last month.
	Yes	No	Quantity	No. of Hours	Code: Enter number of days
1. Simple Wick Lamp	1	2			
2. Hurricane Lantern	1	2			
3. Petromax Lamp	1	2			
4. Wick Stove	1	2			
5. Pressurized Stove	1	2			
6. Refrigerator	1	2			
7. Freezer	1	2			
8. Other, specify	1	2			

SECTION 3. USE OF CANDLES

330. In the past month did your household use candles for illumination?	
Yes 1	
No 2	GO TO 333

331A. How many candles did your household use in the past month?	331B. What is the price of each candle?	331C. What is the average monthly expenditure of the household on candles?	331D. What is the sum of all hours for all candles used during the last 24-hour period? Note: Ask the respondent about the use of each candle .in the household and sum the total hours that the candles are used in the last 24 hours.
Code: Enter number of candles	Code: Enter price in S/.	Code: Enter monthly expenditure in S/.	Code: Enter number of hours/minutes. Hours Minutes

332A. Does your household use candles following purposes?			**332B. In general, what percentage of candle does the household use each month for the following purposes??**	
Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
	Yes	No	Percent	Does not Know
1. Home Use	1	2		-8
2. Family Business Use	1	2		-8
3. Other	1	2		-8
Total			100%	

SECTION 4. USE OF DRY-CELL BATTERIES

333. In the past month did your household use dry cell batteries at home?	
Yes 1	
No 2	GO TO 336

334A. Does your household use batteries of the following sizes?			**334B. In a typical month, how many dry batteries of … did your household use in the past month?**	**334C. What was the price of each battery of size..?**	**334D. In the last month, how much did the household spend on batteries for each size..?**
	Yes	No	Code: Enter number of dry-cell batteries	Code: Enter price in S/. of battery	Code: Enter monthly expenditure in S/.
1. Large (Size D & C)	1	2			
2. Small (size AA &AAA)	1	2			

SECTION 5. USE OF CAR BATTERIES

336. In the past month did your household use car battery to provide electricity at home?

Yes 1
No 2 GO TO 344

337. How many car batteries does your household use at home at the same time?

Code: Enter number of car batteries.

	338A. What is the cost of car battery?	**338B. What is the voltage of the battery?** Enumerator: Ask to see the batteries.							**338C. What is the amperage of the battery?**
	Code: Enter cost in S/. of car battery	Code: Enter voltage of car battery, if no battery, enter -7 if do not know, enter -8							Code: Enter ampere of car battery
Batt. No.		6 V	8 V	12 V	24 V	Other	Do not know	Not Applicable	
1		6	8	12	24		**-8**	**-7**	
2		6	8	12	24		**-8**	**-7**	
3		6	8	12	24		**-8**	**-7**	

338D. If your household used a battery previous to this one, how many months did the previous battery last?

Code: Enter number of months previous battery last.
Does not apply …-7

338E. What is the cost per recharge for the first battery listed?	338F. How many recharges for all car batteries does your household have each month?	338G. How many days does each recharge lasts?	338H. What is the average monthly expenditure for recharging car batteries:	338I. What is the cost of round trip transportation per recharge?
Code: Amount in S/ Does not know…-8	Code: Enter number of recharges.	Code: Enter number of days each recharge lasts.	Code: Enter monthly expenditure in S/.	Code: Enter roundtrip transportation cost in S/.

	339A. Does your household use any of the following INCANDESCENT LIGHT BULBS, which are energized by car batteries?			339B. How many light bulbs of this class does the household use?	339C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
	Type and size of light bulb	Yes	No	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	< 10 Watts	1	2			
2	15 Watts	1	2			
3	25 Watts	1	2			

	340A. Does your household use any of the following FLUORESCENT TUBES, which are energized by car batteries?			340B. How many tubes this class does the household use?	340C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
	Type and size of fluorescent tube	Yes	No	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	10 W (Straight)	1	2			
2	20 W (Straight)	1	2			
3	22 W (Circular)	1	2			

	341A. Does your household use any of the following ENERGY SAVING LIGHT BULBS, which are energized by car batteries?			341B. How many light bulbs of this class does the household use?	341C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours ***that the bulbs are used in the last 24 hours.***	
	Type and size of light bulb	Yes	No	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	7 W or less	1	2			
2	9 Watts	1	2			
3	12 Watts	1	2			
4	18 Watts	1	2			
5	20 Watts	1	2			

342A. Does your household use car battery following purposes?			342B. In general, what percentage of spending on car battery each month is for the following purposes?	
Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
	Yes	No	Percent	Does Not Know
A. Lighting	1	2		-8
B. Cooking	1	2		-8
C. Electric Appliances	1	2		-8
D. Home Business Use	1	2		-8
E. Other	1	2		-8
Total	1	2	100%	

343A. Does the household use the following electric appliances, which are powered by electricity, from car battery?				**343B. How many of each appliance does your household have?**	**343C. What is the average wattage rating of the appliance?** Note: Estimate the average wattage if more than one appliance in use.	**343D. What is the sum of all hours for all appliances used during the last 24-hour period?** Note to enumerators: If the household has more than one appliance of this type, ask the respondent about the use of each appliance in the household and sum the total hours that the appliances are used in the last 24 hours.	
				Code: Enter number of appliances or, if do not use, enter "-7."	Code: Enter the average number of watts of appliances or, if do not use, enter "-7."	Code: Enter the number of hours of use with fraction or, if do not use, enter "-7."	
		Yes	No			Hours	Minutes
1	Radio	1	2				
2	Sound Equipment	1	2				
3	TV, Black-and-White	1	2				
4	TV, Color	1	2				
5	Video Recorder	1	2				
6	DVD	1	2				
7	Others, specify	1	2				

SECTION 6. USE OF LPG

344. In the past month, did your household use LPG at home?	
Yes 1	
No 2	GO TO 348

345A. What size of gas cylinder/ tank does your household use at home?			345B. How many cylinders does your household use in a month?	345C. What is the price per cylinder or tank of LPG?	345D. On an average how much does your household spend per month on LPG?	345E. How many days does ONE cylinder of LPG lasts?
	Yes	No	Code: Enter number of cylinders used in a month	Code: Enter price in S/. per cylinder	Code: Enter monthly expenditure in S/.	Code: Enter number of days one cylinder
1. 10 kg Cylinder	1	2				
2. 45 kg Cylinder	1	2				
3. Other, specify size in kg of cylinder_______	1	2				

346A. Does your household use LPG following purposes?			346B. In general, what percentage of LPG does your household use each month for the following purposes?	
Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
	Yes	No	Percent	Does not Know
1. Lamp lighting	1	2		-8
2. Cooking	1	2		-8
3. Appliances	1	2		-8
4. Home business	1	2		-8
5. Other Specify_____________	1	2		-8
Total			100%	

347A. Does the household use the following GAS appliance?			347B. How many of each appliance does your household have?	347C. What is the sum of all hours for all…used during the last 24-hour period? Note: Ask the respondent about the use of each…in the household and sum the total hours that the …are used in the last 24 hours.		347D. What is the sum of all days for all …used during the last month? Note: Ask the respondent about the use of each…in the household and sum the total days that the…are used in the last month.
				Code: Enter number of hours or, if do not use any, enter "-7."		
Type of Appliance	Yes	No	Code: Enter number of appliances	Hours	Minutes	Code: Enter number of days, or, if do not use any, enter "-7."
1. Gas Lamp	1	2				
2. LPG Stove	1	2				
3. LPG Stove and Oven	1	2				
4. Refrigerator	1	2				
5. Freezer	1	2				
6. Other, specify	1	2				

SECTION 7. USE OF SOLAR PV HOME SYSTEM

348. In the past month did your household use a solar PV home system (SHS) to provide electricity at home?

Yes 1
No 2 GO TO 360

349. The solar PV home system that you use is		
Owned?	1	
Leased?	2	GO TO 351
Rented?	3	Monthly rent S/.
Given to household?	4	GO TO 352
Not applicable	-7	

350. If owned, what was total cost paid in cash for the solar PV home system (include all the components)?
Code: Total cost in S/. Not applicable -7
S/. ____________________ GO TO 352

351A. If leased, how much is the monthly payment?	**351B. If leased, what was the initial payment? (S/.)**	**351C. If leased, how many monthly payments are required?**
Code: Enter the amount of monthly payment Not applicable -7	Code: Enter the number of initial payments in S/. or, if initial payment is not required, enter "0." Not applicable -7	Code: Enter the number of payments. Not applicable -7
S/.	S/.	S/.

352. In which year did the household obtain the solar PV home system?
Code: Enter year the household obtained it (e.g., 1990) Not applicable -7 Does not know -8

353. How much did your household spend on repairs or maintenance of the solar PV home system in the last 12 months? Enumerator: Do not including light bulbs**.**
Code: Enter repair cost in S/. or "0" for no spending on repair
S/.

354. What is the size in watt peak (Wp) of the solar PV system?
Code: Enter size of solar PV in Wp. DOES NOT KNOW…-8
Wp

	355A. Does your household use any of the following INCANDESCENT LIGHT BULBS, which are energized by solar PV system?			**355B. How many light bulbs in this class does the household use?**	**355C. What is the sum of all hours for all bulbs used during the last 24-hour period?** Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
N	Type and size of light bulb	Y	N	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	10 W or less	1	2			
2	15 W	1	2			
3	25 W	1	2			

	356A. Does your household use any of the following FLUORESCENT TUBES, which are energized by solar PV system?			**356B. How many tubes in this class does the household use?**	**356C. What is the sum of all hours for all tubes used during the last 24-hour period?** Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
	Type and size of fluorescent tube	Y	N	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	10 W (Straight)	1	2			
2	20 W (Straight)	1	2			
3	22 W (Circular)	1	2			

	357A. Does your household use any of the following ENERGY SAVING LIGHT BULBS, which are energized by solar PV system?			357B. How many light bulbs in this class does the household use?	357C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
				Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use	
	Type and size of light bulb	Yes	No		Hours	Minutes
1	7 Watts or less	1	2			
2	9 Watts	1	2			
3	12 Watts	1	2			
4	18Watts	1	2			
5	20 Watts	1	2			

358A. Does your household use PV system for the following purposes?			358B. In general, what percentage of solar energy does your household use each month for the following purposes?	
Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
	Yes	No	Percent	Does not Know
1. Lamp Lighting	1	2		-8
2. Cooking	1	2		-8
3. Appliances	1	2		-8
4. Home Business	1	2		-8
5. Other, specify______________	1	2		-8
Total			100%	

	359A. Does the household use the following electric appliances, which are powered by electricity from solar PV system?			359B. How many of each appliance does your household have?	359C. What is the average wattage rating of the appliance? Note: Estimate the average wattage if more than one appliance in use.	359D. What is the sum of all hours for all appliances used during the last 24-hour period? Note to enumerators: If the household has more than one appliance of this type, ask the respondent about the use of each appliance in the household and sum the total hours that the appliances are used in the last 24 hours.	
		Yes	No	Code: Enter number of appliances or, if do not use, enter "-7."	Code: Enter the average number of watts of appliances or, if do not use, enter "0."	Code: Enter the number of hours of use with fraction or, if do not use, enter "-7." Hours	Minutes
1	Radio	1	2				
2	Sound Equipment	1	2				
3	TV, Black-and-White	1	2				
4	TV, Color	1	2				
5	Video Recorder	1	2				
6	DVD	1	2				
7	Others, specify)	1	2				

SECTION 8. ELECTRIC GENERATOR SET

360. In the past month, did your household use electric generator set to provide electricity at home?

Yes 1

No 2 GO TO 372

361. The electric generator set that you use is

Owned? 1

Leased? 2 GO TO 363

Rented? 3 What is the monthly rent (S/.)

Allowed to use by another home or company? 4 GO TO 364

362. If own, what was the total cost paid for the electric generator set (include all components)?
Code: Total cost in S/.
S/.

363A. If leased, how much is the monthly payment?	363B. If leased, what was the initial payment? (S/.)	363C. If leased, how many monthly payments are required?
Code: Enter the amount of monthly payment in S/.	Code: Enter the amount of initial payment in S/. or, if initial payment is not required, enter "0."	Code: Enter the number of monthly payments.
S/.	S/.	S/.

364. In which year did the household obtain electric generator set?
Code: Enter year the household obtain it (e.g., 1990)

	365A. What type of fuel does the electric gen-set use?			365B. How many units of fuel mentioned in 369A did your household used for gen-set last month?.		365C. What is the price per unit?	365D. What is the average monthly expenditure on diesel or gasoline for the electric gen-set?
		Yes	No	No. of units	Type of unit	S/. per unit	S/. per month
1	Diesel	1	2				S/.
2	Gasoline	1	2				

Type of Unit
Gallon …1 Liter …2

366. On an average, how much did your household spend per month on repairs and/or maintenance of electric gen-set?
Code: Enter repair cost per month in S/ or "0" if no spending on repair
S/.

	367A. Does your household use any of the following INCANDESCENT LIGHT BULBS, which are energized by electric generator set?			367B. How many light bulbs in this class does the household use?	367C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
	Type of light bulb	Yes	No	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	25 W	1	2			
2	50 W	1	2			
3	75 W	1	2			
4	100 W	1	2			

	368A. Does your household use any of the following FLUORESCENT TUBES, which are energized by electric generator set?			368B. How many light bulbs in this class does the household use?	368C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
	Type and size of fluorescent tube	Yes	No	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	10 W (Straight)	1	2			
2	20 W (Straight)	1	2			
3	40 W (Straight)					
4	22 W (Circular)	1	2			
5	32 W (Circular)					

	369A. Does your household use any of the following ENERGY SAVING LIGHT BULBS, which are energized by electric generator set?			369B. How many light bulbs in this class does the household use?	369C. What is the sum of all hours for all bulbs used during the last 24-hour period? Note to enumerators: Ask the respondent about the use of each bulb in watt classes of bulbs in the household and sum the total hours that the bulbs are used in the last 24 hours.	
	Type and size of light bulb	Yes	No	Code: Enter the number or "-7" for do not use	Code: Enter hours of use with fraction or "-7" for do not use Hours	Minutes
1	Less than 12 W	1	2			
2	12 W	1	2			
3	18 W	1	2			
4	20W	1	2			
5	25 W	1	2			

	370A. Does your household use electric generator set for the following purposes?			370B. In general, what percentage of your household monthly spending on electric generator set for the following purposes?	
	Code: "0" if none and percentage if applicable Does not know -8 Not applicable -7				
		Yes	No	Percent	Does not Know
1	Lamp Lighting	1	2		-8
2	Cooking	1	2		-8
3	Electric Appliances	1	2		-8
4	Home Business Use	1	2		-8
5	Other, specify	1	2		-8
	Total			100%	

	371A. Does the household use the following electric appliances, which are powered by electricity, from generator set?			**371B. How many of each appliance does your household have?**	**371C. What is the average wattage rating of the appliance?** Note: Estimate the average wattage if more than one appliance in use.	**371D. What is the sum of all hours for all appliances used during the last 24-hour period?** Note to enumerators: If the household has more than one appliance of this type, ask the respondent about the use of each appliance in the household and sum the total hours that the appliances are used in the last 24 hours.	
		Yes	No	Code: Enter number of appliances or, if do not use, enter "-7."	Code: Enter the average number of watts of appliances or, if do not use, enter "-7."	Code: Enter the number of hours of use with fraction or, if do not use, enter "-7." Hours	Minutes
1	Radio	1	2				
2	Sound Equipment	1	2				
3	TV, Black-and-White	1	2				
4	TV, Color	1	2				
5	Video Recorder	1	2				
6	DVD	1	2				
7	Others, specify	1	2				

SECTION 9. USE OF FIREWOOD

372. In the past month, did your household use firewood at home?

Yes 1

No 2 GO TO 376

373. How does your household obtain firewood?

Purchase only	1	
Collect/received only	2	GO TO 375A
Purchase and collect	3	
Other, specify _____	4	

THE FOLLOWING ARE QUESTIONS FOR PURCHASED FIREWOOD.

374A. How much did you spend during the last purchase?		**374B. How many total days will this purchase last?**	**374C. What was the one-way distance traveled (in meters) to make this purchase?**	**374D. How long did it take to travel one way to make this purchase of firewood?**		
Code: Enter amount of money (in S/.) spent last time. **Do not include Transportation Cost* Total		Code: Enter number of days firewood lasts.	Code: Enter distance in kilometers traveled (use fraction for less than 1 km) Does not know…-8	Code: Enter time in hours and minutes.		
S/.	Decimal				Hours	Minutes
				Adult Male		
				Adult Female		
				Child		

THE FOLLOWING ARE QUESTIONS FOR COLLECTED FIREWOOD.

375A. How many times did your household collect firewood last month?	**375B. How many total days did the previous collected firewood last?**	**375C. What was the one-way distance traveled in the previous collection of firewood?**
Code: **Number of collection**	Code: Enter number of days firewood lasts.	Code: Enter distance in meters traveled (use fraction for less than 1 m). Does not know…-8

375D. In the last week, how much time (hours per week) was used in collecting firewood by the following members?		
Code: Enter number of hours or "0" for not spending any time Not applicable -7		
Use Type	**Hours**	**Minutes**
Adult Male		
Adult Female		
Children		

SECTION 10. USE OF BIOMASS RESIDUE

376. In the past month, did your household use biomass residue at home?	
Yes 1	
No 2	GO TO 378

377A. How many times did your household collect biomass residue last month?	377B. How many total days did this collected biomass residue last?	377C. What was the one-way distance traveled in the previous collection of biomass residue? (distance in meters)
Code: **Number of collection**	Code: Enter number of days biomass residue lasts.	Code: Enter distance in meters traveled (use fraction for less than 1 m). Does not know…-8

377D. In the last week, how much time (hours per week) was used in collecting crop residues by the following members?	
Code: Enter number of hours or "0" for not spending any time.	
Use Type	Hours
Adult Male	
Adult Female	
Children	

SECTION 11. ANIMAL DUNG

378. In the past month, did your household use dung at home?	
Yes 1	
No 2	GO TO 380A

379A. How many times did your household collect dung last month?	**379B. How many total days did this collected dung last?**	**379C. What was the one-way distance traveled in the previous collection of dung?** (distance in meters)
Number of collection	Code: Enter number of days dung last.	Code: Enter distance in meters traveled (use fraction for less than 1 m).

379D. In the last week, how much time (hours per week) was used in collecting dung by the following members?	
Code: Enter number of hours or "0" for not spending any time Not applicable -7	
Use Type	Hours
Adult Male	
Adult Female	
Children	

SECTION 12. USE OF COOKING STOVE AND COOKING

We would like to ask about cooking fuels and all the stoves and fires that the household uses during a usual week.

380A. What is the principal type of stove that your household uses to cook meal? Enumerator: Ask respondent if it is possible to see the stove.	**380B. Where is this stove located?** Enumerator: Ask respondent if it is possible to see the stove and area where the stove is located.	**380C. Is there a window or vent in the cooking area?** Enumerator: Ask respondent if it is possible to see the stove and area where the stove is located.	**380D. What type of fuel does your household usually use with this stove?** Enter types of fuels used most often with this stove.	**380E. Does your household use any other kind of fuel with this stove?** Enter the second most often used fuel.	**380F. Who usually starts and tends this stove?** Check the household member ID in Section 200
Code: 1 = open fire (e.g., three-stone); 2 = traditional stove, no chimney; 3 = traditional stove, chimney; 4 = gas/kerosene stove; -7 = not applicable	Code: 1 = outdoor; 2 = semi-enclosed; 3 = separate kitchen; 4 = living area	Code: 0 = none; 1 = one only; 2 = two or more	Code: 0 = none; 1 = firewood; 2 = crop residue or wood chips; 3 = dung; 4 = charcoal; 5 = coal; 6 = kerosene; 7 = LPG; 8 = electricity	Code: 1 = firewood; 2 = crop residue or wood chips; 3 = dung cakes; 4 = charcoal; 5 = coal; 6 = kerosene; 7 = LPG; 8 = electricity	Household member ID (See code number in Section 200)
Code Number	Code Number	Code Number	Code Number	Code Number	Code Number
1.					
2.					
3.					

Annex C. Generic Socioeconomic Impact Questionnaire

What follows is a sample questionnaire with examples of questions that can be asked in a survey for rural electrification projects. The questionnaire is based on previous experience with rural electrification projects around the world; however, it is not a comprehensive template. Ultimately, the final selection/design of questions will depend on the objectives and needs of the particular project, and should be informed by the data gathered in the participatory assessment. While designed for application at the household level, the questionnaire could easily be revised for application at the small- business level.

Table A-C.1 Sample Survey for Rural Electrification Projects

SOCIOECONOMIC AND DEMOGRAPHIC INFORMATION ON ALL MEMBERS													
Person ID number	**Name**	**Relationship with household head**	**Age**		**Sex**	**Marital status**	No. mos. eat & sleep in this HH during past 12 mos.	**Education**			**Reading or studying**	
			Yrs	Mos	M = 1 F = 2	1 = single 2 = divorced 3 = widowed		Can read & write No = 0 Yes = 1	No of yrs. of education completed	Presently enroll in school No = 0 Yes = 1	Hours spent at home reading or studying last 24 hours	Of which hours reading or studying done at night
1												
2												
3												
4												
5												
6												
7 etc.												

Relationship codes					
[0]=Head of household	[1]=Father	[2]=Mother	[3]=Husband	[4]=Wife	[5]=Brother
[6]=Sister	[7]= Son	[8]=Daughter	[9]=Father-in-law	[10]=Mother-in-law	[11]=Brother-in-law
[12]=Sister-in-law	[13]=Son-in-law	[14]=Daughter-in-law	[15]=Uncle	[16]=Aunt	[17]=Cousin (male)
[18]=Cousin (female)	[19]=Nephew	[20]=Niece	[21]=Domestic helper (male)	[22]=Domestic helper (female)	[23]=Grandfather
[24]=Grandmother	[25]=Other (specify)				

Note: Age: Enter the total number of years and months. For example the person is 34 years and 5 months old enter 34 in the years column and 5 in the months column.
Education codes: Number of years of education completed: Enter the total number of years of education the person completed. Enter: - 7 for questions that do not apply, for example answer -7 on education and occupation for infant.

Information on Income, Expenditures, and Agricultural Activities				
Nonagricultural Cash Income				
INC1.0	What was your household's -nonagricultural cash income over the past 12 months?			
INC1.1	Cash income from sale of livestock/fowl/fish	______	INC1.1	
INC1.2	Secondary cash income	______	INC1.2	
INC1.3	Worker wages and bonuses	______	INC1.3	
INC1.4	Government income, such as pension or veterans benefits	______	INC1.4	
INC1.5	Remittances from relatives	______	INC1.5	
INC1.6	Income from interest or rental property, such as land or agricultural equipment	______	INC1.6	
INC1.7	Other cash income, specify	______	INC1.7	
INC1.8	Total noncash income	______	INC1.8	

Agricultural Income					
Please tell me about all the crops your household grew during the past 12 months.					
Type of crops	Total amount		Price per unit	Total production expenses	Total revenue (net)
	Production	Sold			
	AG1.0	AG1.1	AG1.2	AG1.3	AG1.4
	AG2.0	AG2.1	AG2.2	AG2.3	AG2.4
	AG3.0	AG3.1	AG3.2	AG3.3	AG3.4
	AG4.0	AG4.1	AG4.2	AG4.3	AG4.4
	AG5.0	AG5.1	AG5.2	AG5.3	AG5.4
	AG6.0	AG6.1	AG6.2	AG6.3	AG6.4

Note: Total expenses must include the expenses incurred, such as land rental fees, fertilizer, and workers' wages. The number of crops in the questionnaire must reflect the variety of crops grown in the survey area.

Nonagricultural Expenditures				
EX1.0	What were your household's-nonagricultural expenditures last year?			
EX1.1	Food and foodstuff	______	EX1.1	
EX1.2	Housing, such as repair or rent (excluding rent for agricultural production)	______	EX1.2	
EX1.3	Medical care	______	EX1.3	
EX1.4	Other expenditures	______	EX1.4	
EX1.5	Total nonagricultural expenditures	______	EX1.5	

Agricultural Land				
LA2.0	Please describe your land that was under cultivation last year (in hectares).			
LA2.1	Total area under cultivation	______	LA2.1	
LA2.2	Portions of fields that were irrigated	______	LA2.2	
LA2.3	Portions of fields flooded	______	LA2.3	

Livestock Holdings				
LI3.0	Please describe the livestock currently raised by your household.			
LI3.1	Pigs	______	LI3.1	
LI3.2	Cattle and/or water buffalo	______	LI3.2	
LI3.3	Domestic fowl	______	LI3.3	
LI3.4	Other, specify	______	LI3.4	

Housing Unit Information

HU3.1 Main type of dwelling unit ______ HU3.1 [ ]

[1] = Row house (wood construction)
[2] = Row house (brick construction)
[3] = Row house (brick and wood construction)
[4] = Semidetached home
[5] = Single, detached home
[6] = Apartment
[7] = Other, specify............

HU3.2 Is any part of your house used for business activity or commercial purposes? ______ HU3.2 [ ]

Coding: [0] = No, If "No," go to HU3.5; [1] = Yes

HU3.3 If part of your house is used for business activity, please indicate type. ______ HU3.3 [ ]

[1] = Crop processing
[2] = Hair salon or barber shop
[3] = Food/beverage shop
[4] = Grocery and beverage shop
[5] = Beverage shop
[6] = Retail sales
[7] = Laundry
[8] = Furniture-making or carpentry shop
[9] = Handicraft production/sales
[10] = Repair shop (e.g., appliances)
[11] = Other, specify

HU3.4 If "Yes," *who in your household* is the principle operator of the above business activities? ______ HU3.4 [ ]

Enter person identification number shown in "Socioeconomic and Demographic Information."

HU3.5 Does your household own or rent this house?
Coding: [0] =Own; [1] = Rent ______ HU3.5 [ ]

Access to Social Infrastructure

	What is the distance from your home to the nearest elementary school?			
INF1a		______________ kilometers	INF1a	
INF1b		________________ meters	INF1b	
	What is the distance from your home to the nearest secondary school?			
INF2a		______________ kilometers	INF2a	
INF2b		__________________ meters	INF2b	
	What is the distance from your home to the nearest health center or health clinic?			
INF3a		______________ kilometers	INF3a	
INF3b		__________________ meters	INF3b	
INF3	What is the source of your household **drinking** water supply Code: [1] = Tapb water inside home [2] = Tap water outside home but within the household premise; [3] = Tube well (privately owned) [4] = Tube well (government owned) [5] = Well [6] = Pond [7] = River/canal			
	What is the distance from your home to the nearest drinking water source mentioned above? (Enter "0" for tap inside home)			
INF4a		______________ kilometers	INF3a	
INF5b		__________________ meters	INF3b	
INF6	What is the source of your household **nondrinking** water supply Code: [1] = Tap water inside home [2] = Tap water outside home but within the household premise; [3] = Tube well (privately owned) [4] = Tube well (government owned) [5] = Well [6] = Pond [7] = River/canal			
	What is the distance from your home to the nearest **nondrinking** water source mentioned above? (Enter "0" for tap inside home)			
INF7a		______________ kilometers	INF7a	
INF7b		__________________ meters	INF7b	
INF8	What is the best description of the main access to your home? Code: [1] = Paved road/street [2] = Unpaved road/street [3] = Path to walk [4] = River/canal/sea [5] = Other			

Fuels and Energy Sources			
	Code: [0]=No [1] = Yes		
EG1	Candle	EG1	
EG2	Kerosene /diesel for lamp lighting	EG2	
EG2	Torch	EG2	
EG3	Solar lantern/lamp	EG3	
EG4	Fuelwood	EG4	
EG5	Charcoal	EG5	
EG6	Animal dung	EG6	
EG7	Charcoal	EG7	
EG8	Biogas	EG8	
EG9	Coal	EG9	
EG10	Crop residues	EG10	
EG11	LPG	EG11	
EG12	Dry cell battery	EG12	
EG13	Car battery	EG13	
EG14	Solar PV home system	EG14	
EG15	Household-owned electric generator set	EG15	
EG16	Electric generator set owned by neighbor/local supplier	EG16	
EG17	Electricity from the privately owned minigrid, village/ community grid	EG17	
EG18	Electricity from national grid, or regional grid, or town grid	EG18	
EG19	Others, specify ______________________	EG19	

Candles			
CAN1	During the past 12 months how often did your household use candles?	CAN1	
	Code: [0] = Do not use candles, ***go to next section*** [1] = Used sometimes/seldom [2] = Always		
CAN2	How many candles does your household buy per purchase?	CAN2	
CAN3	On the average, how much does your household spend on candles at each purchase?	CAN3	
CAN4	How many days does your typical purchase of candles last?	CAN4	
CAN5	On average, how much does your household spend on candles each month?	CAN5	
CAN6	What is the average weight (in grams) of one candle?	CAN6	
	Uses of candlelight for household activity		
	Now I would like to ask you some questions about evening activities that require candlelight		
	Do any household members use candlelight in the evening for the following purposes:.		
CAN7	**Reading/writing/studying** (i.e., read newspaper, bible, novel, write letter, do homework for school, prepare for examination)		
	[1] = Yes; [0] = No	CAN7	
CAN8	**Area lighting** [1] = Yes; [0] = No	CAN8	
CAN9	Generally, how many hours per evening does your household usually use candles for lighting? ________Hours/evening	CAN9	
Torches			
TO1	During the past 12 months how often did your household use a torch/ torches for lighting?	TO1	
	[0] = Do not use torch for lighting If "Do not use torch'" go to next section. [1] = Used sometimes/seldom [2] = Always		
TO2	On average, how much does your household spend on torch each month? _______per month	TO2	
TO3	**Area lighting** [1] = Yes; [0] = No; If "No" ***go to next section***	TO3	
TO4	Generally, how many hours per evening does your household usually use a torch/torches for lighting? _________Hours per evening	TO4	

Kerosene			
KER1	**During the past 12 months how often did your household use kerosene?**	KER1	
	Code: [0] = Do not use kerosene, ***go to next section*** [1] = Used sometimes/seldom [2] = Always		
KER2	On average, how many liters of kerosene does your household usually buy per purchase?	KER2	
KER3	What percentage of the kerosene you buy per purchase is used for the following purposes?		
KER3a	Cooking and boiling water for drinking, %	KER3a	
KER3b	Heating water (for bathing, washing clothes), %	KER3ab	
KER3c	Lighting, %	KER3c	
KER3d	For home business, %	KER3d	
KER3e	Other, % (specify)	KER3e	
	(Total must add up to 100%)	Total	100%
KER4	On average, how much does your household spend on kerosene per purchase?	KER4	
KER5	On average, how many days does your typical purchase of kerosene last?	KER5	
KER6	On average, how much does your household spend on kerosene per month?	KER6	
KER6a	How much kerosene did your household use last month?	KER6a	
KER6b	What was the average price of kerosene that you paid last month?	KER6b	

Uses of Lamps/Lanterns			
KL1	How many simple wick kerosene lamps does your household have? *(Enter "0" for none, if "None"* ***go to next section***	KL1	
	Do you or any of your household members use simple kerosene wick lamps for the following purposes.		
KL2	**Reading/writing/studying** (i.e., read newspaper, bible, novel, write letter, do homework for school, prepare for examination) [1] = Yes; [0] = No	KL2	
KL3	**Area lighting** [1] = Yes; [0] = No	KL3	
KL4	On average, how many hours per day does your household use simple wick lamps?	KL4	
KL5	How many regulated wick lamps (hurricane lanterns, e.g., Coleman, Petromax) does your household have? *(Enter "0" for none, if "None"* ***go to next section.****)*	KL5	
	Do any household member use regulated wick lamps for the following purposes:		
KL6	**Reading/writing/studying** (i.e., read newspaper, bible, novel, write letter, do homework for school, prepare for examination) [1] = Yes; [0] = No	KL6	
KL7	**Area lighting** [1] = Yes; [0] = No	KL7	
KL8	On average, how many hours per day does your household use regulated wick lamps?	KL8	
KL9	How many pressurized kerosene lamps does your household have? *(Enter "0" for none, if "None"* ***go to next section)***	KL9	
	Do any household member use pressurized kerosene lamps for the following purposes.		
KL10	**Reading/writing/studying** (i.e., read newspaper, bible, novel, write letter, do homework for school, prepare for examination) [1] = Yes; [0] = No	KL10	
KL11	**Area lighting** [1] = Yes; [0] = No	KL11	
KL12	On average, how many hours per day, does your household use pressurized kerosene lamps?	KL12	
	Do any of the household members use a solar lamp/lantern for the following purposes:		
KL13	**Reading/writing/studying** (i.e., read newspaper, bible, novel, write letter, do homework for school, prepare for examination) [1] = Yes; [0] = No	KL13	
KL14	**Area lighting** [1] = Yes; [0] = No	KL14	
KL15	On average, how many hours per day does your household use the solar lamp/lantern?	KL15	

Dry-Cell Battery			
DBAT1	During the past 12 months did your household use a dry cell battery for any of the following applications: torch, radio, tape cassette, other? Code: [0] = Do not use dry cell battery, ***go to next section*** [1] = Used sometimes/seldom [2] = Always	DBAT1	
DBAT2	On average, how many dry cell batteries does your household buy per purchase? *Enter number of dry cell batteries usually buy regardless of size*	DBAT2	
DBAT3	On the average, how much does your household spend on dry cell batteries per purchase?	DBAT3	
DBAT4	On average, how many days does your typical purchase of dry cell batteries last?	DBAT4	
DBAT5	On average, how much does your household spend on dry cell batteries per month?	DBAT5	

	ITEM	Do you use dry cell battery for any of these devices? [0] = No [1] = Yes	No. of hrs. used per day	No. of batteries used to operate the device
DBAT6	Flashlight	DBAT6a	DBAT6b	DBAT6c
DBAT7	Battery-powered lamp	DBAT7a	DBAT7b	DBAT7c
DBAT8	Radio and/or tape cassette	DBAT8a	DBAT8b	DBAT8c
DBAT9	Other, specify ________________	DBAT9a	DBAT9b	DBAT9c

Motorcycle/Car Battery			
CBAT1	During the past 12 months, did your household use car or motorcycle battery to supply electricity? Code: [0] = Do not use motorcycle/car battery, ***go to next section*** [1] = Used sometimes/seldom [2] = Always	CBAT1	
CBAT2	During the past 30 days, did your household use a motorcycle/car battery to supply electricity? Code: [0] = No, did not use, ***go to CBAT3*** [1] = Used as supplementary source of electricity [2] = Used as the main source of electricity *If answered [1] or [2]"* ***go to CBAT4***	CBAT2	
CBAT3	What are your reasons for not using car battery during the past 30 days? Code: [1] = Out of order [2] = Recharge is too costly [3] = No transportation [4] = Others, specify ____________________	CBAT3	
CBAT4	How many storage (car) batteries does your household have? If the household has more than 2 car batteries, only ask for the most often used.	CBAT4	
CBAT5 First Battery			
CBAT5a	What is the voltage of your first car battery?	CBAT5a	
CBAT5b	What is the amp-hour rating of your first car battery?	CBAT5b	
CBAT5c	How much did the first car battery cost?	CBAT5c	
CBAT6 Second Battery			
CBAT6a	What is the voltage of your second car battery?	CBAT6a	
CBAT6b	What is the amp-hour rating of your second car battery?	CBAT6b	
CBAT6c	How much does the second car battery cost?	CBAT6c	
CBAT7a	How many months did your previous battery last? *(Enter "0" if you did not own any battery before)*	CBAT7a	

Questions for All Car Batteries			
CBAT8	On the average, how many days per week does your household use electricity from storage/car battery (ies)?	CBAT8	
CBAT9	On the average, how many hours per day does your household use electricity from storage/car battery (ies)?	CBAT9	
CBAT10	On the average, how many times in a month does your household recharge your battery?	CBAT10	
CBAT11	How much does each recharge cost?	CBAT11	
CBAT12	On the average, how much do you spend on recharging all your batteries each month?	CBAT12	
CBAT13	How many days does the battery give you electricity before the next recharge?	CBAT13	
CBAT14	How far (in km) is the recharging station from your home? (If less than 1 kilometer, indicate fraction)	CBAT14	
CBAT15	Which mode of transport does your household use to go to the recharge station? Code: [0] = Walk [1] = Bicycle/rickshaw/motorcycle [2] = Boat [3] = Car/truck [4] = Bus [5] = Animal/animal driven [6] = Other, specify [Align codes and col 1 entries]________	CBAT15	
CBAT16	What is the average round-trip transportation cost (in local currency) to the recharging station? (Enter "0" for no transportation cost incurred.)	CBAT16	
CBAT17	What type of energy source does your battery charging station use? Code: [1] = Grid [2] = Solar [3] = Microhydro [4] = Diesel generator-set	CBAT17	

	Item	Do you use a car battery for any of these devices? [0] = No [1] = Yes	Average no. hours used per day
CBAT18	Black & white TV	CBAT18a	CBAT18b
CBAT19	Color TV	CBAT19a	CBAT19b
CBAT20	Radio and/or tape cassette	CBAT20a	CBAT20b
CBAT21	Karaoke	CBAT21a	CBAT21b
CBAT22	Video VCR/VCD machine	CBAT22a	CBAT22b
CBAT23	Lighting appliances	CBAT23a	CBAT23b
CBAT24	Other appliances/ equipment, specify ________________	CBAT24a	CBAT24b

Solar PV System			
PV0	During the past 12 months how often did your household use solar PV system? Code: [0] = Do not use solar PV system, ***if not, go to next section*** [1] = Used sometimes/seldom [2] = Always	PV0	
PV1	Please tell me whether electricity supply which you are using now is: Code: [1] = Not enough for household need [2] = Just enough for household need [3] = More than enough for household need	PV1	
PV2	What is the size (in watt-peak, Wp) of the solar PV panel?	PV2	
PV3	What is the rating (in Amp-hour) of the battery/battery system used for PV system?	PV3	
PV4	On the average, how many **hours per day** do you usually use your PV home system?	PV4	
PV5	On the average, how many **days per week** do you usually use your PV system?	PV5	

Does your household use solar PV home system for the following devices, and if "yes" how many hours does your household use/day?
If for example, use only 2 days in a week and one hour each day, calculate the average hours used per day over 7 days, use decimal point if needed.

	Item	Do you use a solar PV system for any of these devices? [0] = No [1] = Yes	Average no. hours used per day
PV5a	Black & white TV		
PV5b	Color TV		
PV5c	Video (VCR/VCD)		
PV5d	Radio		
PV5e	Karaoke /tape cassette		
PV5f	Lighting devices		
PV5g	Fan (table/ceiling)		
PV5h	Refrigerator		
PV5i	Iron		

PV5j	Electric stove/oven		
PV5k	Electric mixer/grinder		
PV5l	Security light		
PV5m	Other (specify)		

Did your PV system need any repairs in the past 12 months?

PV6	Code: [0] = No, ***go to PV9*** [1] = Yes	PV6	
PV7	If yes, which part has broken down? Code: [0] = No [1] = Yes		
PV7a	Lamp	PV7a	
PV7b	Charge/discharge controller	PV7b	
PV7c	Inverter	PV7c	
PV7d	Solar panel/module	PV7d	
PV7e	Ballast	PV7e	
PV7f	Others, specify ___________________________	PV7f	
PV8	How much is the total cost (in local currency) of repair including materials and labor for the items enumerated above for the past 12 months?	PV8	
PV9	What year did you acquire your PV system?	PV9	
PV10	How did you acquire it? Codes: [1] Loan/rent to own, ***go to PV11*** [2] Cash payment, ***go to PV12*** [3] Rented , ***go to PV13*** [4] Through project, ***go to next section*** [5] Other, specify _____________________, ***go to next section***	PV10	
PV11	**If acquired through loan:**		
PV11a	What is the total cost (in local currency) of your system?	QPV11a	
PV11b	Have you paid off your loan? Code: [0] = No [1] = Yes	QPV11b	
PV11c	How much is your initial down payment?	QPV11c	
PV11d	What is your monthly amortization?	QPV11d	
PV11e	What is the maturity (in months) of your loan? (Enter 60 if more than 5 years)	QPV11e	
PV12	If paid in cash, what is the total cost (in local currency) of your system?	PV12	
PV13	If rented, how much (in local currency) the monthly rental?	PV13	

Small Electric Generator Set			
GEN1	Does your household use electricity generated from diesel generator set (gen-set)?	GEN1	
	Code: [0] = Do not use, ***go to next section*** [1] = Use electricity from village/community or private entrepreneur-owned generator –set [2] = Use electricity from neighbor/relative generator set [3] = Use electricity from family- owned generator set, ***go to next question*** [4] = Others, specify________________________		
GEN2	How many months has your household been using electricity from village- or neighbor- owned gen-set?	GEN2	
GEN3	On average, how many **hours per day** does your household receive electricity services from the above source?	GEN3	
GEN4	On average, how many **days per month** does your household receive electricity services from the above source?	GEN4	
GEN5	How many households including your household are sharing electricity from the same source?	GEN5	
GEN6	How much (in local currency) does your household pay for electricity per billing period?	GEN6	
GEN7	How many days does each bill cover?	GEN7	
GEN8	How is your household charged for electricity bills?	GEN8	
	Code: [1] = Charged by kWh used, ***go to GEN9*** [2] = Charged by number of lightbulbs/tubes or appliances, ***go to GEN10*** [3] = Charged by agreed fixed monthly fee, ***go to next section*** [4] = Other methods, please specify _________________		
GEN9a	**KWh Billing** If household is charged/pays by kWh, how much electricity does your family usually use (kWh) per billing period?	GEN9a	
GEN9b	How much does electricity cost (in local currency) per kWh?	GEN9b	
GEN10a	**Load Billing** If household is charged/pays by number of lightbulbs or tubes and/or appliances, how many lightbulbs or tubes and/or appliances does your household have?	GEN10a	

GEN10b	What is the average wattage of all light bulbs or tubes and appliances?	GEN10b	
GEN11	**Family-Owned Gen-set** How many gen-sets does your household have?	GEN11	
GEN12	How many months has your household been using your own electric gen-set to generate electricity?	GEN12	
GEN13	What do you think about the price of your gen-set?	GEN13	
	Code: [1] = Very expensive [2] = Expensive [3] = Right price [4] = Cheap		
GEN14	How much (in local currency) did you spend in purchasing your gen-set?	GEN14	
GEN15	What is the rating in kVA of your gen-set?	GEN15	

Status of Connection To Electric Grid, Consumption, and Expenditures			
ELE0	What is the name of the utility company providing electricity services in your area?	ELE0	
ELE1	How many months have you had your electricity connection? __________ months.	ELE1	
ELE2	How many customers share the same electric meter?	ELE2	
	[0] = If the utility company providing services does not install meter to its customers. [1] = Do not share meter with other. [2] = Your household and one other customer [3] = Your household plus 2 other customer [4] = Your household plus 3 other customer [5] = Other		
ELE3	What is the source of your electricity connection?	ELE3	
	[1] = Utility (name) [2] = Neighbor/relative who is connected through utility [3] = regional/provincial/town electricity services [4] = Neighbor/relative who connect to regional/provincial/town electricity services [5] = Other, specify		
ELE4	Who do you pay for your electricity services: [1] = Utility (name)	ELE4	
	[2] = Neighbor/relative who pays to utility [3] = Regional/provincial/town electricity services [4] = Neighbor/relative who pays to regional/provincial/town electricity services [5] = Other, specify		
ELE5	On average, how much does your household pay for electricity for each billing period? _________ (in local currency)	ELE5	
ELE6	How many days does each bill cover? __________days	ELE6	
ELE7	How does your household pay your monthly electricity bill?	ELE7	
	[1] = Pay by kWh used [2] = Pay per number of lightbulbs/tubes & appliances [3] = Fixed monthly cost (If answer [2] or [3] go to ELE9a)		
ELE8	If pay by kWh used, how much does your household pay per kWh _________ per kWh	ELE8	

ELE9	If pay by number of lightbulbs/tubes or appliances or fixed monthly cost:		
ELE9a	How many lightbulbs/tubes do you have? _____ lightbulbs/tubes	ELE9a	
ELE9b	What is the average wattage of all lightbulbs/tubes? ______ Watts	ELE9b	
ELE10	Does your household use electricity to cook rice? [1] = Yes; [2] = No	ELE10	
ELE11	Does your household use electricity to boil water? [1] = Yes; [2] = No	ELE11	
ELE12	Does your household use electricity for radio/tape? [1] = Yes; [2] = No	ELE12	
ELE13	Does your household use electricity for TV? [1] = Yes; [2] = No [Delete following rule]	ELE13	
ELE14	Does your household use electricity for other appliances? (specify) [1] = Yes; [2] = No	ELE14	
Quality of Electricity Services			
ELE15	How many hours during the day do you have electricity service? _______ hours during the day	ELE15	
ELE16	How many hours during the evening/nighttime do you have electricity service? _______ hours	ELE16	
ELE17	Do you use any of the following sources of energy to supplement electricity? Code: [1] = Yes; [0] = No	ELE17	
ELE17a	Candles	ELE17a	
ELE17b	Kerosene/diesel lamp	ELE17b	
ELE17c	Pressurized lamp	ELE17c	
ELE17d	Car/motorcycle battery	ELE17d	
ELE17e	On average, how much does your household spend per month to supplement electricity?	ELE17e	
ELE18	How many times last month did your household experience power failures that lasted more than 15 minutes? (*If none enter "0"*)	ELE18	
ELE19	How often last month did your household experience dimming or have difficulty turning lights or other appliances? Code: [1] = Often [2] = Rarely [3] = Never	ELE19	

Electric Appliance Ownership and Use *			
EA1.1	How many **plug-in radios** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA1.1	
EA1.2	On average, how many hours per day does your household use your plug-in radio? *(Enter total hours of all plug-in radios use)*	EA1.2	
EA1.3	What is the wattage rating of your plug-in radio? (If own more than one enter the average wattage rating)	EA1.3	
EA2.1	How many **wind-up or battery operated radios** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA2.1	
EA2.2	On average, how many hours per day does your household use your wind-up/battery operated radio? *(Enter total hours of all wind-up/battery operated radios in use)*	EA2.2	
EA2.3	What is the wattage rating of your wind-up/battery operated radio? *(If own more than one enter the average wattage rating)*	EA2.3	
EA3.1	How many **b&w TVs** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA3.1	
EA3.2	On average, how many hours per day does your household use your b&w TV? *(Enter total hours of all b&w TVs used)*	EA3.2	
EA3.3	What is the wattage rating of your b&w TV? *(If own more than one enter the average wattage rating)*	EA3.3	
EA4.1	How many **color TVs** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA4.1	
EA4.2	On average, how many hours per day does your household use your color TV? *(Enter total hours of all color TVs used)*	EA4.2	
EA4.3	What is the wattage rating of your color TV? *(If own more than one enter the average wattage rating)*	EA4.3	
EA5.1	How many **fans** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA5.1	
EA5.2	On average, how many hours per day does your household use your fan? *(Enter total hours of all fans used)*	EA5.2	
EA5.3	What is the wattage rating of your fan? *(If own more than one enter the average wattage rating)*	EA5.3	
EA6.1	How many **nonelectric flatirons** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA6.1	
EA6.2	On average, how many hours per day does your household use your nonelectric flatiron? *(Enter total hours of all nonelectric flatirons used)*	EA6.2	

EA7.1	How many **electric flatirons** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA7.1	
EA7.2	On average, how many hours per day does your household use your nonelectric flatiron? *(Enter total hours of all electric flat irons used)*	EA7.2	
EA7.3	What is the wattage rating of your electric flatiron? *(If own more than one enter the average wattage rating)*	EA7.3	
EA8.1	How many **water heaters** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA8.1	
EA8.2	On average, how many hours per day does your household use your water heater? *(Enter total hours of all water heaters used)*	EA8.2	
EA8.3	What is the wattage rating of your water heater? *(If own more than one enter the average wattage rating)*	EA8.3	
EA9.1	How many **rice cookers** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA9.1	
EA9.2	On average, how many hours per day does your household use your rice cooker? *(Enter total hours of all rice cookers used)*	EA9.2	
EA9.3	What is the wattage rating of your rice cooker? *(If own more than one enter the average wattage rating)*	EA9.3	
Ea10.1	How many **refrigerators** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA10.1	
Ea10.2	What is the wattage rating of your refrigerator? *(If own more than one enter the average wattage rating)*	EA10.2	
EA11.1	How many **washing machines** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA11.1	
EA11.2	On average, how many hours per day does your household use your washing machine? *(Enter total hours of all washing machines used)*	EA11.2	
EA11.3	What is the wattage rating of your washing machine? *(If own more than one enter the average wattage rating)*	EA11.3	
EA12.1	How many **nonelectric drills** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA12.1	
EA12.2	On average, how many hours per day does your household use your nonelectric drill? *(Enter total hours of all nonelectric drills used)*	EA12.2	
EA13.1	How many **power drills** does your household have? *(Enter "0" for none, if "none" **go to next appliance**)*	EA13.1	

EA13.2	On average, how many hours per day does your household use your power drill? *(Enter total hours of all power drills used)*	EA13.2	
EA13.3	What is the wattage rating of your power drill? *(If own more than one enter the average wattage rating)*	EA13.3	
EA14.1	How many **nonelectric saws** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA14.1	
EA14.2	On average, how many hours per day does your household use your nonelectric saw? *(Enter total hours of all nonelectric saws used)*	EA14.2	
EA15.1	How many **power saws** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA15.1	
EA15.2	On average, how many hours per day does your household use your power saw? *(Enter total hours of all power saws used)*	EA15.2	
EA15.3	What is the wattage rating of your power saw? *(If own more than one enter the average wattage rating)*	EA15.3	
EA16.1	How many **video players (VCR/VCD)** does your household have? *(Enter "0" for none, if "none"* ***go to next appliance****)*	EA16.1	
EA16.2	On average, how many hours per day does your household use your video player (VCR/VCD)? *(Enter total hours of all video players used)*	EA16.2	
EA16.3	What is the wattage rating of your video player (VCR/VCD)? *(If own more than one enter the average wattage rating)*	EA16.3	
EA17.1	How many **karaoke machines** does your household have? *(Enter "0" for none, if none"* ***go to next appliance****)*	EA17.1	
EA17.2	On average, how many hours per day does your household use your karaoke machine? *(Enter total hours of all karaoke machines used)*	EA17.2	
EA17.3	What is the wattage rating of your karaoke machine? *(If own more than one enter the average wattage rating)*	EA17.3	
EA18.1	Others (specify)	EA18.1	

* The specific appliances in this section should be determined based on information gathered in the Participatory Assessments, and should include both electric and non-electric appliances.

Electric Lighting			
Incandescent Bulbs (INC) (Bulbs used for more than 30 minutes daily only)			
INC1	25 [MAKE LOWER CASE]		
INC1.1	Number of bulbs	INC1.1	
INC1.2	Total hours used per day	INC1.2	
INC2	40 [LOWER CASE]		
INC2.1	Number of bulbs	INC2.1	
INC2.2	Total hours used per day	INC2.2	
INC3	50 [lower case]		
INC3.1	Number of bulbs	INC3.1	
INC3.2	Total hours used per day	INC3.2	
INC4	60 [LOWER CASE]		
INC4.1	Number of bulbs	INC4.1	
INC4.2	Total hours used per day	INC4.2	
INC5	100 [lower case]		
INC5.1	Number of bulbs	INC5.1	
INC5.2	Total hours used per day	INC5.2	
Fluorescent Tubes (TUB) – Straight and Circular (Tubes used for more than 30 minutes daily only)			
TUB1	10 watts straight		
TUB1.1	Number of tubes	TUB1.1	
TUB1.2	Total hours used per day	TUB1.2	
TUB2	20 watts straight		
TUB2.1	Number of tubes	TUB2.1	
TUB2.2	Total hours used per day	TUB2.2	
TUB3	40 watts straight		
TUB3.1	Number of tubes	TUB3.1	
TUB3.2	Total hours used per day	TUB3.2	
TUB4	22 watts circular		
TUB4.1	Number of tubes	TUB4.1	
TUB4.2	Total hours used per day	TUB4.2	

TUB5	32 watts circular		
TUB5.1	Number of tubes	TUB5.1	
TUB5.2	Total hours used per day	TUB5.2	
Compact Fluorescent Lamps (Only those used 30 or more minutes per day)			
COM1	Less than 12 watts		
COM1.1	Number of tubes	COM1.1	
COM1.2	Total hours used per day	COM1.2	
COM2	12 Watts		
COM2.1	Number of tubes	COM2.1	
COM2.2	Total hours used per day	COM2.2	
COM3	18 Watts		
COM3.1	Number of tubes	COM3.1	
COM3.2	Total hours used per day	COM3.2	
COM4	20 Watts		
COM4.1	Number of tubes	COM4.1	
COM4.2	Total hours used per day	COM4.2	
COM5	25 Watts		
COM5.1	Number of tubes	COM5.1	
COM5.2	Total hours used per day	COM5.2	
Reasons for Adopting/Purchasing and Not Adopting/Purchasing Electricity			
RSN1	Would you like to have access to electricity, or would you prefer to continue using your present energy sources?	RSN1	
	Code: [1] = Electricity [0] = Prefer present energy sources		
Reason for not connecting to grid electricity			
RSN2	Please give me reasons why you prefer present energy sources. Code: [0] = No; [1] = Yes		
RSN2a	Can't afford to pay for the costs associated with connection	RSN2a	
RSN2b	Can't afford to pay for wiring house	RSN2b	
RSN2c	Can't afford to pay monthly usage fee of electricity	RSN2c	
RSN2d	Can't afford to buy electrical equipment	RSN2d	

RSN2e	See no application	RSN2e	
RSN2f	Satisfied with present energy sources	RSN2f	
RSN2g	Other, specify	RSN2g	
Reasons for connecting to grid electricity			
	Please tell me the Reason why your household decided to obtain electricity. Code: [0] = No; [1] = Yes		
RSN3a	For children's education	RSN3a	
RSN3b	For better lighting	RSN3b	
RSN3c	For entertainment	RSN3c	
RSN3d	For information/news	RSN3d	
RSN3e	To improve income-generating opportunities	RSN3e	
RSN3f	Electricity we are using is cheaper than kerosene and other fuels.	RSN3f	
RSN3g	Other (specify)	RSN3g	
Reasons for Not Purchasing Off-grid Electricity System *			
	Please give me reasons why did your household decide not to purchase an off-grid electricity system. Code: [0] = No; [1] = Yes		
OFF1a	Do not have enough money to pay for the system	OFF1a	
OFF1b	Do not think that the system could supply enough electricity for use at home	OFF1b	
OFF1c	Do not want to borrow money from anyone	OFF1c	
OFF1d	See no applications	OFF1d	
OFF1e	Satisfied with present energy sources	OFF1e	
OFF1f	Other, specify	OFF1f	

Attitudes/Perceptions * *			
The following statements concern electricity use and other issues. Please tell me if you strongly agree, agree, are indifferent, disagree, or strongly disagree with these statements. *Use the following codes for answers*: Code: [1] = Strongly agree [2] = Agree [3] = Indifferent/neutral [4] = Disagree [5] = Strongly disagree			
ATT1	Having electricity is important for my children's education.	ATT1	
ATT2	Because of good light, children study more at night.	ATT2	
ATT3	Presently in my house, it is easy to read in the evening.	ATT3	
ATT4	Reading is easier with electric lights/lamps compared to candles or kerosene lamps/lanterns.	ATT4	
ATT5	Presently, it is difficult for my family to get news and information.	ATT5	
ATT6	My family is extremely happy with the energy we get from our current fuels/sources.	ATT6	
ATT7	Using kerosene or diesel can cause health problems.	ATT7	
ATT8	Car batteries are a good source of electricity.	ATT8	
ATT9	Solar PV is a good source of electricity.	ATT9	
ATT10	Electricity is very beneficial to housework/childcare.	ATT10	
ATT11	Electricity is important to our water supply.	ATT11	
ATT12	We often socialize with friends, relatives, or neighbors at our home in the evening.	ATT12	
ATT13	Compared to 10 years ago, life is better for my family today.	ATT13	
ATT14	Compared to 10 years ago, life is better for me today.	ATT14	
ATT15	I would rather wait for electricity from the grid than invest in an off-grid electric system.	ATT15	
ATT16	Buying an off-grid electric system is one of my family's investment priorities.	ATT16	
ATT17	Buying solar PV home system is one of my family's investment priorities.	ATT17	
ATT18	Monthly electric bill is or would be a financial burden for my family.	ATT18	
ATT19	Monthly spending for nonelectric energy sources is/was a financial burden for my family.	ATT19	
ATT20	If someone/government/NGO/bank were willing to lend me money to buy a solar PV system, I would seriously consider it.	ATT20	

ATT21	If solar PV were to become easily available, I would seriously consider buying it even if I have to try to borrow money to pay for it.	ATT21	
ATT22	If grid electricity were to become available, I would seriously consider connecting to the grid even if I have to borrow money to pay for the connection.	ATT22	
ATT23	I feel safe in my house in the evening.	ATT23	
ATT24	I feel safe outside my house in the evening.	ATT24	
ATT25	Electricity makes it easier to get news and information.	ATT25	
ATT26	Watching TV provides my family with great entertainment.	ATT26	
ATT27	News and information from radio and television provide good knowledge for everyone in the family.	ATT27	
ATT28	News and information from radio and television provide good information relevant for conducting business.	ATT28	
ATT29	News and information from radio and television provide good information about agricultural activities	ATT29	
ATT30	News and information from radio and television provide good knowledge on family health issues.	ATT30	

* This section should be specific to the type(s) of off-grid system(s) available (e.g., solar PV system, diesel gen-set, etc.), and should be determined by the specific needs of the project.
** These statements should be specific to the energy sources/energy systems relevant to the local context and project objectives/needs, and should be informed by the information generated in the Participatory Assessment.

Time Use

Average time allocation by adult on various activities yesterday.

Give proportion of time spent on various activities by male and female household members yesterday (time in hours and minutes). All answers should be for a 24-hour period, except TU4 and TU5, which should be for a one-week period. Translate any (M) minutes into hours (H). Total should sum to 24 hours.

TU1	Food processing (grinding, flour making, pounding)	_______ M H	Hours	TU1	
TU2	Fuel collection	_______ M H	Hours	TU2	
TU3	Cooking (including cleaning dishes, pots and pans) and serving (including carrying food to field)	_______ M H	Hours	TU3	
TU4	Water fetching	_______ M H	Hours	TU4	
TU5	Washing clothes and household cleaning	_______ M H	Hours	TU5	
TU6	Taking meals	_______ M H	Hours	TU6	
TU7	Bathing and/or beautifying yourself	_______ M H	Hours	TU7	
TU8	Caring of children (e.g., bathing, feeding, dressing)	_______ M H	Hours	TU8	
TU9	Food shopping, inc. trip to market, and other shopping	_______ M H	Hours	TU9	
TU10	Income-producing activities (agriculture, animal grazing, care of business, etc.)	_______ M H	Hours	TU10	
TU11	Resting (day nap, night sleep)	_______ M H	Hours	TU11	
TU12	Leisure time (watching TV for fun, listening to radio for fun, socializing)	_______ M H	Hours	TU12	
TU13	Religious practices, i.e., praying	_______ M H	Hours	TU13	
TU14	Watching TV	_______ M H	Hours	TU14	
TU15	Reading, studying, or doing homework	_______ M H	Hours	TU15	
TU16	Listening to radio	_______ M H	Hours	TU16	
TU17	Other, specify	_______ M H	Hours	TU17	

Annex D. Conversion Factors for Kerosene and Electric Lighting

		Light Output	Lighting per Energy Value	
Incandescent	**Watts**	**Lumens**	**klmh/kgOE**	**klmh/kWh**
25 Watt	25	230	109.12	9.20
40 Watt	40	430	127.50	10.75
50 Watt	50	580	137.58	11.60
60 Watt	60	730	144.30	12.17
100 Watt	100	1280	151.81	12.80
Florescent				
10 Watt	10	600	711.63	60.00
20 Watt	20	1200	711.63	60.00
40 Watt	40	1613	478.27	40.33
Compact Florescent				
Philipps 15 Watt L11	15	894	706.88	59.60
Osram Sol Lamp L13	6.14	240	463.60	39.09
Non-Electric Lights				
Paraffin Candle	60	11.8	2.33	0.20
Kerosene Wick	118	11.4	1.15	0.10
Kerosene Hurricane	198	32	1.92	0.16
Kerosene Pressure	1380	2040	17.53	1.48

Source: Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1988.

IDB