A JOINT REPORT ON ENERGY ACCESS

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Meeting Challenges, Measuring Progress

The Benefits of Sustainable Energy Access in Latin America and the Caribbean

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Contents

Boxes

Figures

Tables

Foreword

With electricity coverage at more than 96 percent, Latin America and the Caribbean (LAC) is close to becoming the world's first developing region to achieve universal access to electricity. Over slightly more than four decades, electricity coverage in the region has grown from about 50 percent to more than 90 percent. Some LAC countries have fared better than others, and lack of electricity service is still substantial in the region, with about 22 million people that still do not enjoy these benefits. The region still has a high dependence on biomass fuels, with more than 80 million people relying on firewood and charcoal for cooking, using fuel-inefficient primitive stoves. These traditional cooking technologies emit a significant amount of indoor air pollution (IAP), which has been linked to respiratory illnesses and adverse environmental impacts resulting from unsustainable biomass use.

Energy is an essential prerequisite for development, and universal access to sustainable energy is aligned with one of the key principles of the 2030 Agenda of leaving no one behind. Universal energy access will contribute to poverty eradication, education, gender equality, access to quality medical care, reduced infant mortality, and environmental sustainability. Providing energy to those still without access requires solutions based on multiple factors, including institutional and regulatory frameworks, technology, environmental and social contexts, and economic viability. It also requires a multi-stakeholder approach involving both public- and private-sector participation to accelerate the implementation of projects. Equally important is knowledge sharing on successful experiences of business models, regulatory and institutional arrangements, and innovation.

Today there is a great opportunity for innovation and efficiency in a region where creative business models for promoting sustainable energy have been designed and implemented. Furthermore, the region´s ambitious Nationally Determined Contribution targets can help promote the transformative changes necessary to tackle climate change while enhancing positive social impacts.

This joint study of the Inter-American Development Bank (IDB) and the United Nations Development Programme (UNDP) provides a comprehensive reference of methodological approaches to define energy poverty, measure the progress and impact of energy-access policies and programs, and improve their results based on successful cases. This knowledge-dissemination initiative offers cutting-edge methodologies for program design and sharing of our experiences and vision for reaching sustainable energy for all in the LAC region.

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Abbreviations and Acronyms

B&W	Black and White (TV)
CNE	National Energy Commission (Nicaragua)
CO	Carbon Monoxide
CO2	Carbon Dioxide
CONAFE	National Electric Power Company (Chile)
ECLAC	United Nations Economic Commission for Latin America and the Caribbean (CEPAL)
EDI	Energy Development Index
ESMAP	Energy Sector Management Assistance Program
FOSE	Fund for Social Compensation of Electricity (Peru)
GACC	Global Alliance for Clean Cookstoves
GHG	Greenhouse Gas
GTF	Global Tracking Framework
IAP	Indoor Air Pollution
IDB	Inter-American Development Bank
IEA	International Energy Agency
ISO	International Standards Organization
LAC	Latin America and the Caribbean
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goal
MFI	Microfinance Institution
NGO	Nongovernmental Organization
OLADE	Latin American Energy Organization
PM	Particulate Matter
PV	Photovoltaic
REN21	Renewable Energy Policy Network for the 21st Century
SDG	Sustainable Development Goal
SEforAll	Sustainable Energy for All (formerly SE4All)
SHS	Solar Home System
SWER	Single-Wire Earth Return
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization

Executive Summary

Energy access has proven to be a key factor in economic, social, and human development. As a result, the measurement of energy access has gained significant attention from governments and development agencies over the last 20 years. The Millennium Development Goals (MDGs) were established in the year 2000 to quantify and monitor such basic development indicators as eradicating poverty, achieving universal education, and ensuring environmental sustainability. At that time, energy was not a formal MDG; rather, it was considered a necessary condition for achieving them. By 2011, with the launching of the United Nations Sustainable Energy for All (SE4All) initiative, that view had changed, and the role of basic energy services was considered key to achieving the MDGs. In 2015, the new United Nations Sustainable Development Goals (SDGs) explicitly recognized affordable and clean energy as a goal and a key factor in development, alongside education and poverty alleviation. Recently, the initiative was restructured and is now called SEforALL. It mobilizes international development agencies around a global action agenda. International donors, countries, and the private sector have supported the initiative to help people in developing countries gain access to modern energy services.

Impact evaluation, detailing how and to what extent policies and interventions contribute to socioeconomic gains for society, has gained recognition over the past decade. Evaluation now is considered an essential component of project development. Impact evaluations are important for identifying key lessons for future policies and investments. Thus, this report pairs the progress on improving energy access in the Latin America and Caribbean (LAC) region with examining ways to measure and evaluate the impact of energy policies and programs.

LAC's Energy Access Situation

The level of electricity coverage in the LAC region is much higher than in other parts of the developing world. In 2016, LAC's average electrification rate was 96.6 percent (OLADE 2017), compared to much lower levels in such regions as Africa and South Asia (IEA 2017). But the rate of electricity access in LAC still lags behind those of such developed regions as Europe, North America, and Asia.

The Latin American Energy Organization (OLADE) has normalized the electricity coverage rates for each country in LAC based on both census and industry estimates (table ES-1). OLADE estimates that, as of 2016, a total of 21.8 million people in LAC were still without electricity. The majority of these people live in rural areas, while some reside in urban slums. With the exception of Haiti, electrification rates in the LAC region are generally quite high, but are lower in rural versus urban areas.

Haiti stands out as a country with extremely low levels of electricity access; the dearth of progress in that country is quite unusual, compared with the rest of LAC. Less than one-third of households in Haiti have electricity, and this lack of coverage has been caused by institutional and political issues. Given Haiti's high population densities, extending electricity to those without service would be less costly than in other countries of the region that must deal with more remote populations.

Table ES-1. Electricity access in LAC countries, 2016

Country	Electricity coverage (%)	Country	Electricity coverage (%)
Argentina	98.8	Guyana	88.2
Barbados	99.8	Haiti	30.0
Belize	93.0	Honduras	75.1
Bolivia	88.0	Jamaica	98.0
Brazil	99.3	Mexico	98.6
Chile	99.7	Nicaragua	90.1
Colombia	97.0	Panama	92.4
Costa Rica	99.3	Paraguay	99.1
Cuba	99.6	Peru	95.1
Dominican Republic	97.1	Suriname	90.3
Ecuador	97.2	Trinidad & Tobago	98.0
El Salvador	96.0	Uruguay	99.7
Grenada	98.1	Venezuela	98.9
Guatemala	92.1		

Source: OLADE 2017.
Note: The figures represent electricity access provided by grid-based systems.

Therefore, within the region, priority should be given to solving some of the financial and institutional barriers that are causing low levels of electricity access in Haiti.

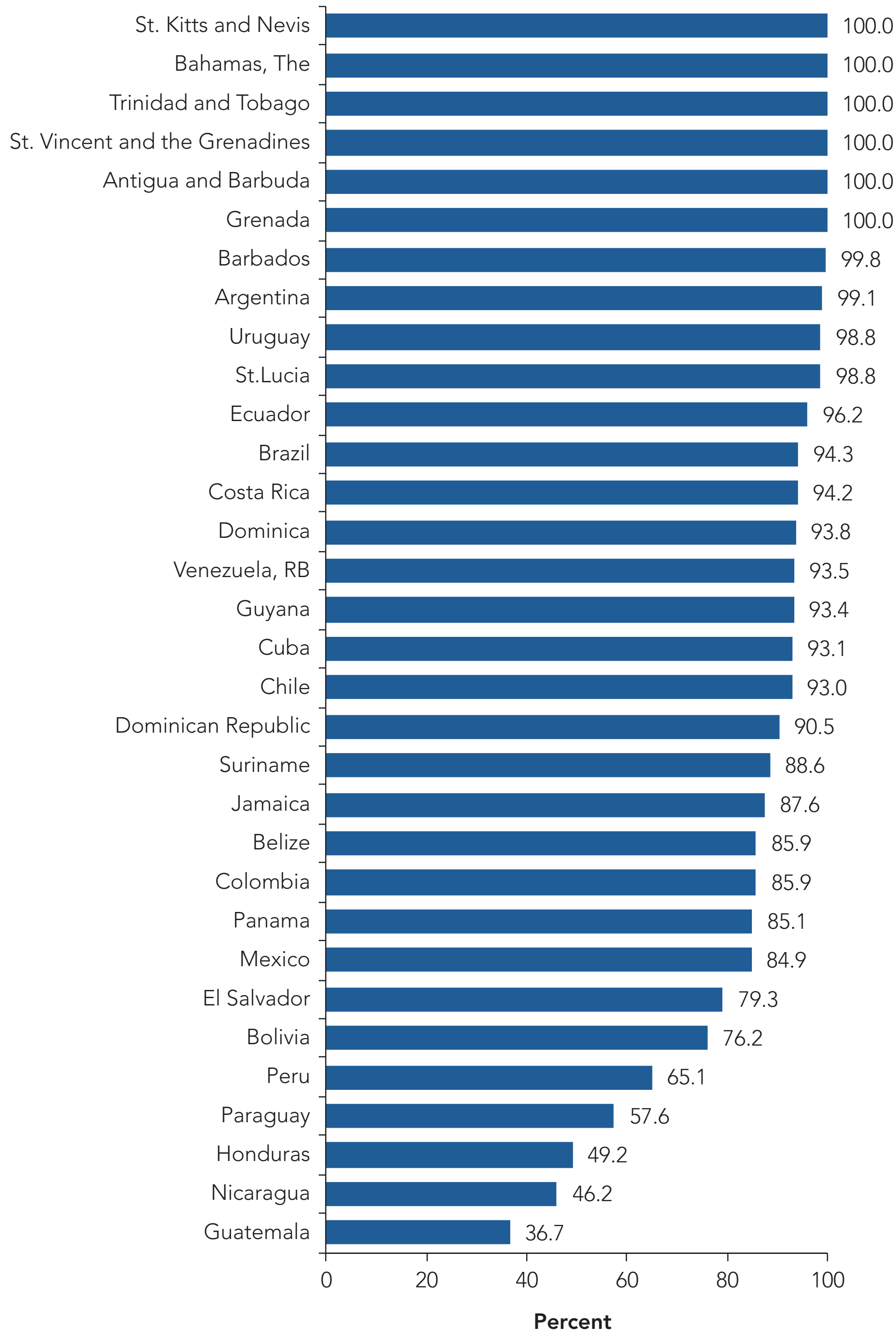
Dependence on solid fuel–fired cooking in the LAC region is also quite high, comprising a total of 80 million people (figure ES-1). These solid fuels comprise mainly biomass, such as firewood and charcoal (World Bank 2014). In Haiti, for example, 90 percent of the population uses firewood or charcoal for cooking, while more than half of households in Guatemala, Nicaragua, and Honduras cook with solid fuels. In terms of absolute numbers, Mexico has the largest number of people cooking with biomass fuels, at 15.7 million, followed by Brazil at 10.8 million.

Approaches to Defining Energy Poverty

The variation between cooking and electricity usage makes it difficult to exactly define the energy poor. The approach to defining energy poverty in LAC has been influenced by international research and the views of international agencies. The three main approaches to defining energy poverty are (i) measurement of an energy poverty line, (ii) use of energy development indicators, and (iii) classification of households in multiple tiers of energy use.

The first approach involves discovering an energy poverty line—an income point below which energy use and/or expenditures remain the same, implying the bare minimum of energy needed for households (Barnes, Khandker, and Samad 2011). The goal of this approach is to develop policies and programs to lift people out of energy poverty. The energy poverty line is determined by income, after controlling for a variety of exogenous household and socioeconomic factors. To be in energy poverty, households must have an energy consumption level below a threshold amount that is insensitive to household income. This is not to imply that energy consumption is insensitive to income as a whole; instead,

Figure ES-1. Access to modern cooking fuels in LAC, 2014



Source: World Bank 2014.
Note: Modern cooking fuels include kerosene, LPG, and electricity.

it means that low-income households reach a threshold of basic energy consumption, such as minimum cooking and lighting, necessary for life.

The second approach uses a multidimensional indicator, known as the Energy Development Index (EDI), to rank countries based on their access to modern energy services. Using statistics compiled by the International Energy Agency (IEA), the EDI measurement approach considers the degree of energy access by households and communities, combining them into one index.[1] The EDI is meant to rank countries, and there is no cutoff point that defines energy poverty. Because of measurement challenges, the index excludes the cross-cutting characteristics of energy service.

The third approach, which classifies households based on their energy use, is called the Global Tracking Framework (GTF). Based on a collaboration between the World Bank and the IEA, the GTF approach covers fewer countries and considers that it is insufficient to measure access alone. The concept defines energy poverty by going beyond simple binary access to energy. Instead, it applies a framework with a wider set of attributes to define access to modern energy services. Indicators assess whether energy is reliable, of high quality, affordable, and legal to use. A multitier framework includes household, productive, and community uses of energy (World Bank 2015a, 2016b). Using multiple indicators, the idea is to capture the multidimensionality of energy use for measures that can be monitored and tracked at the country level.

Impact Evaluation Methods

Impact evaluation has gained recognition over the last decade as an essential component of project development. Impact evaluations detail 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 energy access policies and investments. Measurement of the physical infrastructure costs of energy projects (e.g., lines, poles, and photovoltaic [PV] systems) is generally straightforward. Measuring benefits is more complicated and might involve the implementation of national or regional surveys and the use of statistical techniques. Two common approaches for measuring benefits are consumer surplus and regression-based techniques.

Consumer Surplus

Consumer surplus, defined as the difference between what consumers are willing to pay and what they actually pay for a product or service, is a standard technique to measure project benefits. Willingness-to-pay measurement techniques account for all the less expensive benefits that will be enjoyed from a product or service made possible through adopting a new technology. 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. Consumer surplus monetizes such benefits by examining patterns of lighting demand before and after a household receives electricity. Willingness to pay includes consumer preferences which are subjective. Measurement of willingness to pay can be achieved by analyzing the demand for services and the prices actually paid by such services offered by electricity.

The demand-curve approach to measuring consumer surplus requires a consumer survey that measures consumer demand for energy services based on specific technologies. This type of analysis involves observing differing consumption patterns when household customers switch from a technology involving a higher price for an energy service to one involving a lower price for that service. For example, once a household has access to electricity, it usually switches from using higher-priced lighting (e.g., kerosene lanterns) to lower-priced lighting (e.g., one or more electric lamps). In a before-and-after or with-and-without situation, the demand curve can be

1. To address concerns that its original energy access indicator was too narrow, the IEA recently expanded the primarily household measurement of energy service to include community-level indicators. Household indicators include access to clean cookstoves and minimal levels of electricity usage, while community-level indicators cover the presence of schools, hospitals and clinics, water and sanitation services, and productive uses.

Box ES-1. Consumer Surplus Application in Peru

In Peru, the consumer surplus approach has been successfully used to estimate the benefits of having electricity services. Applied to lighting, it was found that switching from kerosene or candles to electric lighting resulted in benefits of US$5–28 per month per household, depending on expenditure levels (Meier et al. 2010). Even at the low end of the range, the economic benefits were substantial. Not only did households with electricity enjoy much higher levels of service, they also obtained a real income gain since their total expenditure on lighting service decreased.

The approach was also applied to estimating the benefits of television viewing (see table below). Taking into account the total monthly hours, the monthly benefit of television viewing (consumer surplus) was estimated at 10.48 soles per month for B&W TVs and 24.38 soles per month for color TVs. Color TVs were not used in households that had electricity from car batteries. The net benefit of switching from plug-in B&W TVs to plug-in color TVs (consumer surplus) was estimated at 13.9 soles per month.

Viewing hours and costs for three TV types

	Car battery, B&W	Grid, plug-in B&W	Grid, plug-in color
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

Source: Meier et al. 2010.
Note: Exchange rate: 3.2 soles equal 1 US dollar.

constructed from a consumer survey. By observing the price differences as measured in the survey, the potential savings can be calculated. The LAC region has some interesting examples of projects that have successfully used this type of methodology. In Peru, for instance, television viewing hours were measured for households with and without grid electricity (box ES-1). Many households in areas without electricity use car batteries in order to watch TV, but due to the high price of service, watch for fewer hours. LAC can use more accurate benefit estimation techniques, including consumer surplus, to justify increasingly high-cost projects in its more remote, rural areas.

Regression-Based Techniques

Using direct measurement techniques, the regression-based approach generally addresses whether the development of modern energy services is a cause or an effect of development outcomes. This method aims to capture the spillover effects of energy access, which are important to evaluate the full economic benefits of a project. Thus, whenever possible, rigorous impact evaluation techniques based on multivariate models are preferred.

Measuring the impact of modern energy services for any change in development outcome must address

whether the intervention is the cause of the effect, making it necessary to assess a counterfactual situation. A counterfactual is defined as an outcome that would only occur as a result of some type of intervention. To illustrate, one can consider two identical households without electricity. One household is provided with electricity service. Over time, both households change because of other circumstances. However, the one with electricity has a different set of changes that can be attributed directly to having access to electricity.

Generally, the counterfactual is estimated using a credible comparison group, known as a control group. The goal is to come up with participant and nonparticipant groups 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 (Gertler et al. 2011). Thus, the main advantage of using this approach is its ability to capture economic spillover. However, its main disadvantages are the need for a large amount of data and the challenges of defining a comparable control group.

Measuring the Benefits of Clean Cooking

The non-health, monetary benefits of clean cooking can be measured in fairly direct ways. Using cleaner fuels or improved biomass stoves can result in less time spent collecting fuelwood and cooking. The avoided time spent collecting fuelwood can be estimated by comparing the time spent on this task by users of traditional and clean stoves. For those that purchase firewood or charcoal, the reduced expenditure on fuel consumption is another benefit of clean cooking. The avoided cost of purchasing firewood can be counted as a monetary benefit.

Devising methods to measure the monetary benefits of clean cooking is complicated by the health issues linked to the inhalation of cooking smoke. The health outcomes of clean cooking can be modeled by examining the values of the avoided incidence of short-term illness linked to IAP, avoided days lost due to illnesses, and avoided costs of treatment. These are very real benefits that can be measured in evaluating clean cooking.

Among many populations, reduction in hours of food preparation due to clean cooking may actually have a higher annual monetary value than the reduction in diseases caused by IAP. Measuring the health benefits is complicated by the fact that the consequences of daily smoke inhalation may only be suffered in future years. The negative impacts of cooking with traditional stoves among healthy adults may manifest once or twice a year. By contrast, collecting fuelwood is commonly a daily or weekly task; thus, any reductions can add up to significant monetary values over the course of a year. **Such complicated issues could be resolved by using a more systematic monetary approach to researching the link between the adoption of clean cooking practices with reduction in drudgery and improvements in health.**

Providing LAC Sustainable Energy Access

In recent years, a large number of manufacturers, distributors, and suppliers have created new technologies to meet the requirements of modern, sustainable energy services. The availability of new types of equipment can provide energy services for rural populations without grid connections. This new business line represents a complementary way to provide electricity traditionally made through conventional extension of electricity distribution networks. For the vast number of people in more remote areas of LAC who are still without electricity—and who are unlikely to receive grid-based access in the foreseeable future—grid extension, off-grid community networks, and stand-alone households systems will all be needed.

Grid-Based Electricity

The expansion of grid electricity is a stepwise process that can gradually advance access, even in quite remote regions. Along with the commitment of LAC governments, certain principles must be followed in order to provide modern forms of energy to people without such services (box ES-2).

Box ES-2. Government of Peru Expands Commitment to Both Grid and Off-Grid Electricity Access

Characterized by stable political and economic conditions, Peru has promoted the expansion of both grid and off-grid electrification systems to connect most of its rural populations. In 2005, the country's rural electrification rate was just 30 percent. Recognizing the adverse effects that low levels of electrification can have on quality of life and opportunities for economic development, the Peruvian government set a goal of raising the rural electrification rate in its annual National Plan for Rural Electrification (PNER). Though it still has a way to go, the country has already achieved a rural electrification rate of over 70 percent.

Source: World Bank 2015b.

Within LAC, well-planned and carefully targeted grid rural electrification programs can provide the remaining last mile customers enormous social and economic value. Best practices to promote last-mile grid expansion include the use of low-cost network designs, well-designed tariffs, involving local communities, and provision of subsidies for capital rather than operating costs (Barnes 2007). However, these are not prescriptive solutions. In practice, many ways have been found to successfully develop programs for modern energy access.

Off-Grid Electricity for Households and Communities

The innovative approaches developed to service LAC's remaining remote populations without electricity include small, decentralized community grids and household systems. Many types of renewable energy sources are available for supplying electricity. In most cases, people in isolated rural areas can receive a supply through decentralized PV systems. In some cases, decentralized or micro-grid distribution systems integrating renewable-energy technologies (e.g., small hydroelectric plants, PV plants, and wind and hybrid systems) can be developed. It is necessary to define the appropriate models for supplying electricity to isolated rural communities, including models for both businesses and rural community associations.

Three basic sets of actors are necessary for promoting small-scale electricity systems. The first set comprises institutions to manage energy funds that can provide financing or partial subsidies to participating organizations (e.g., retailers, MFIs, NGOs, and dedicated government departments). In Chile, existing regional development funds were used to reach out to the country's final 3 percent of people without electricity access (box ES-3). Generally, such institutions can also help with technical assistance and establishing system standards as a requirement of loans. The second set of actors needed consists of MFIs and NGOs, whose role is to organize demand, provide customer support, and collect loan payments. Finally, the third set comprises retailers, who sell equipment for cash and provide product guarantees.

Box ES-3. Serving Last-Mile Electricity Customers in Chile's Remote Areas

About 10 percent of Chile's population live in rural areas, and, by 2013, more than 97 percent had electricity. Today, virtually all of the country's remaining people without electricity access—some 20,000 mainly indigenous peoples—live in rural areas and will likely require off-grid solutions using renewable energy sources. In Coquimbo, a remote arid and semi-arid region in northern Chile (Region IV), solar photovoltaic (PV) energy has a tremendous potential to service last-mile electricity customers. The government has developed a PV program to reach these remaining populations without access. Such programs contain elements of new models that could provide electricity using small-scale systems.

Sources: Feron, Heinrichs, and Cordero 2016b; CONAFE.

Providing energy services to remote populations is not a one-dimensional task. Many individual projects have succeeded in single locations, but often have not been replicable without extensive, and sometimes wasteful, subsidies. This situation suggests that governments need to assume more managerial functions throughout the entire process of ensuring access to affordable, modern energy for all. One needed element is a central institution, such as a financial entity or energy fund, to champion the cause of energy access. Such an institution would be responsible for quality control, making energy services affordable (not free), and allocating responsibility of project development and administration to participating enterprises. Though some countries have made progress, challenging work remains in order to reach the very poor and most remote populations. Achieving this in LAC will require balancing public-sector provisions of support with allowing private-sector organizations develop innovative solutions to solve energy access issues.

Looking Ahead

The importance of rural and sustainable energy for developing country economies should not be underestimated, particularly given LAC's focus on market reform. The effects of rural energy cut across diverse facets of rural life—from income and labor productivity to education and women's health. The problems rural people face in obtaining safe, clean, and reliable energy supplies are not minor inconveniences. They represent a significant barrier to rural economic development and improved social well-being. A multifaceted approach to solving rural energy problems for remote or underserved populations is not only warranted; it is essential for future development. For example, the promotion of renewable energy, including solar PV, has achieved a remarkable measure of success in LAC. Even so, the technical and socioeconomic issues associated with scaling up household and village electrification require capacity building at national and local levels.

The LAC region has come a long way in providing both grid and off-grid electricity services. This has been achieved in diverse ways. In Peru, for example, SHSs are being marketed by qualified private-sector companies with subsidies from existing electricity customers. In Chile, a regional development fund provides grid electricity companies financing for stand-alone SHSs. Households pay a minimum charge for electricity, while regional companies provide support for system operation and maintenance. In Ecuador, a public service law now allows a wide variety of businesses to promote electricity among remote populations. For one SHS project, subsidies were justified based on better analysis of electricity benefits. Such diverse initiatives offer lessons for future projects seeking to reach out to people in poor and remote regions.

The daunting challenge now facing many LAC countries is how to provide electricity and clean cooking solutions to their most remote and poorest populations. The road ahead will be difficult, requiring innovative financial and institutional approaches rather than the traditional methods of the past. This is not the time to rest on past accomplishments. Rather, the task ahead is to reach out to those who still lack the means for improving their lives and engaging in the future.

Chapter 1

Introduction

Energy access has proven to be a key factor in economic, social, and human development. As a result, the measurement of energy access has gained significant attention from governments and development agencies over the last 20 years. The Millennium Development Goals (MDGs) were established in the year 2000 to quantify and monitor such basic development indicators as eradicating poverty, achieving universal education, and ensuring environmental sustainability. At that time, energy was not a formal MDG; rather, it was considered a necessary condition for achieving them. By 2011, with the launching of the United Nations Sustainable Energy for All (SE4All) initiative, that view had changed, and the role of basic energy services was considered key to achieving the MDGs. In 2015, the new United Nations Sustainable Development Goals (SDGs) explicitly recognized affordable and clean energy as a goal and key factor in development, alongside education and poverty alleviation. Recently, the initiative was restructured to mobilize international development agencies around a global action agenda. Now called SEforAll, the initiative is supported by international donors, countries, and the private sector to help people in developing countries gain access to modern energy services.

The increasing recognition of energy's important role in achieving development objectives highlights the reality that many people in the world still lack access to basic energy services. In many urban areas of developing countries, where typically there is access to some electricity, the poor face many other challenges, including irregular supply and frequent blackouts. For those without service, affordability, owing to high connection fees, is a major concern. Informal or illegal connections, which are commonly found in urban centers, can impact a city's overall electricity supply. Illegal connections also pose a safety hazard due to poor household wiring and lack of safety devices.

Impact evaluation, detailing how and to what extent policies and interventions contribute to socioeconomic gains for society, has also gained recognition over the last decade and is now considered an essential component of project development. Impact evaluations are important for identifying key lessons for future policies and investments. Thus, this report pairs the progress on improving energy access in the Latin America and Caribbean (LAC) region with examining ways to measure and evaluate whether energy policies and programs have the anticipated development impacts, such as improvements in education, productivity, and quality of life.

The recent emphasis on measurable progress in achieving development goals raises the bar for development agencies in ensuring that projects and programs positively affect development outcomes. The purpose of this report is to review the LAC region's progress toward achieving energy access and evaluate the ways to measure how such improvements translate into better lives for the energy poor.

Benefits of Increasing Energy Access

In most parts of the world, electricity is considered essential for development. Its availability is considered to improve quality of life and increase economic activity. Electricity can benefit rural or poor areas in myriad ways, including improving business and farm productivity, making household tasks more convenient, and providing a more efficient form of household lighting. Areas without access to modern energy are generally poor (Barnes 2014; World Bank 2008; Cabraal, Barnes, and Agarwal 2005). Taken alone, however, electricity does not lead to any development because its effectiveness requires intermediary inputs (e.g., appliances, including lamps for lighting; availability of books for reading; and schools for educating students). When implementing rural electrification schemes that aim to improve energy access, it should not be forgotten that the benefits of such programs are enhanced by investments in complementary infrastructure and the local availability of appliances for purchase (Barnes 2007; Meier et al. 2010; World Bank 2015a).

The main beneficiaries of energy-access improvement programs are households and local community businesses and facilities (e.g., hospitals and schools) without electricity or clean-burning, fuel-efficient methods of cooking and heating. Households benefit in multiple ways from the use of electricity. These benefits might include income growth because of the ability to run small businesses in the evening, increased employment because of the development of local job opportunities, or better education of children because of their ability to study at night due to improved household lighting. Electricity also plays a role in the effective functioning of communities and local institutions. For example, street lighting brings a sense of public security, leading to more travel at nighttime. Electricity in schools may improve student performance or attract qualified teachers to more remote areas where they otherwise would not consider living. At the global level, electricity might possibly lower a country's dependence on kerosene, thus reducing greenhouse gas (GHG) emissions.

The promotion of clean cooking solutions can also have a significant positive effect on households that still depend on wood and other solid fuels to meet their daily cooking needs. Better stoves and cleaner-burning cooking fuels, such as liquefied petroleum gas (LPG), can reduce both indoor air pollution (IAP) in homes and ambient pollution in communities. It has been proven that reduction in IAP is linked to a variety of health improvements, including fewer respiratory illnesses and cataracts.

Despite energy's importance for social and economic development, the lack of energy services remains substantial in the more remote areas of the LAC region. Approximately 21.8 million people in the region are without electricity access, while 80 million still cook with solid fuels (World Bank 2014; OLADE 2017). For many LAC countries, the lack of electricity creates impediments for development. In remote or poor areas, the low level of average household income has a major influence on adoption of electricity and clean cooking methods. Households in such areas sometimes experience difficulty paying monthly electric bills or purchasing appliances that provide energy services for lack of small-scale financing.

Today there are better ways to provide energy access. Recent innovations in business models, combined with the declining cost of new technologies, can help alleviate the lack of access to quality energy. Some of these business models are appropriate for providing energy services to the LAC region's economically disadvantaged populations.

Contribution of Modern Energy to the Sustainable Development Goals

The SEforAll (formerly SE4All) initiative has three main objectives to be achieved by 2030. The first is universal access to modern energy services, meaning that all households should have access to clean cooking fuels and electricity. The second is a doubling of the share of renewable energy sources (e.g., wind, geothermal, solar photovoltaic

[PV] cells, biogas, and other forms of clean energy) in the global energy mix. The third is a doubling the rate of energy efficiency. The SEforAll initiative has provided guidance for international development agencies and has resulted in commitments around a global action agenda. Along with global financial institutions, some 90 countries have committed to pursuing policies to increase reliance on renewable energy and improve energy efficiency.

The 2030 Agenda for Sustainable Development of the United Nations, adopted by heads of state in September 2015, has 17 SDGs with 169 associated targets. SDG 7, devoted exclusively to energy, aims to achieve access to affordable, reliable, sustainable, and modern energy for all. According to the plans, technologies should be developed for supplying modern energy services for everyone in developing countries, including least developed countries, small island nations, and landlocked nations. The time frame for achieving this goal is between now and 2030. Under SDG 7, supplying "modern energy services" implies that the primary purpose is to satisfy basic human needs; however, it also involves productive uses. Supplying modern energy services would make communication, cooking of food, and water boiling more convenient. Homes would be able to have modern forms of space conditioning to create more livable and productive conditions. It would also make possible the milling of grain, refrigeration of perishable products, and lighting of homes.

The availability of modern energy would make it easier to achieve the other SDGs. For example, energy is important for alleviating poverty (SDG 1). It is also necessary for improved food security, better nutrition, and sustainable agriculture (SDG 2). In addition, energy is important for economic growth and improving employment (SDG 8). Jobs will be created in food processing and preservation (e.g., fruit and fish drying, grain drying, heating of water used to process milk, bread baking, operating water irrigation systems for agricultural crops, and refrigerated conservation of perishables products). Furthermore, the use of modern energy facilitates the operation of water pumping systems, in turn, contributing to better water and sanitation systems (SDG 6).

SDG 3 involves improving health services so that they contribute to the promotion of well-being for people of all ages. The effective preservation of medicines requires energy to operate refrigeration systems. Energy services are also needed for sterilizing medical equipment and to provide lighting during surgeries and deliveries at nighttime. Electricity is also important for promoting quality education and the availability of adult learning opportunities (SDG 4). As part of schools, modern communication services and computers can be used to achieve better educational outcomes. Energy services can also be important for improving women's working conditions and participation in important community activities, thereby contributing to equality between the sexes, which is in line with achieving gender equality and empowering women and girls (SDG 5).

Achieving universal access to affordable and reliable modern energy services entails significant challenges. Energy policies, strategies, and action plans must be developed to assist in the implementation of the SDGs. A global alliance backed by financial resources will be necessary for implementing the goal of sustainable development. The need for such an alliance is reflected in the Addis Ababa Agenda for Action,[2] which indicates that concrete measures are important for the 2030 Agenda for Sustainable Development.

Organization of This Report

This report is organized into six chapters. Chapter 2 examines the energy access situation in LAC. At present, numerous ways are available to describe the relationship between energy, poverty, and development. Without access to modern forms of energy, people will have a difficult time rising out of poverty. Chapter 3 explores the issue of energy poverty in depth, while chapter 4 examines the impact of greater energy access. Chapter 5 addresses the important question of what can be done to accelerate the process of ensuring access to modern and

2. Resolution A/69/313 The Addis Ababa Action Agenda of the Third International Conference on Financing for Development (Addis Ababa Action Agenda), adopted by the General Assembly on July 27, 2015.

sustainable energy. The answer requires an analysis of the favorable conditions needed to overcome barriers to providing such services. The experience gained by the United Nations Development Programme (UNDP) and the Inter-American Development Bank (IDB) in promoting projects and programs will be important for countries as they move forward in achieving the SDGs. Finally, chapter 6 discusses the challenges ahead.

Chapter 2
Energy Access Situation in LAC

Most populations in the Latin America and Caribbean (LAC) region have access to modern sources of energy. Electricity coverage is widespread, and modern cooking with liquefied petroleum gas (LPG) is common, especially in urban areas. Yet some 30 million people remain without electricity, while 80 million lack access to clean cooking methods. Most of those without access to modern energy services live in poor and remote areas. Thus, despite the substantial progress made in recent decades, the region still has a long way to go to achieve universal access to modern energy services.

Evolution of Electricity Coverage

As of 2016, some 1.1 billion people worldwide—about 14 percent of the global population—were without electricity (IEA 2015b, 2017). LAC has a much higher level of electricity coverage compared to other developing regions. In 2016, its average rate of electrification was 96.6 percent, which was substantially higher than those of Africa and South Asia (OLADE 2017). However, its electricity access rate still lags behind those found in such developed regions as Europe, North America, and Asia.

The Latin American Energy Organization (OLADE) has developed a method to normalize the electricity coverage rates for each country in LAC (table 2-1). Many countries in the LAC region base their reporting of electricity coverage on the national census, which includes questions related to whether or not households have electricity. Another information source on the rate of electrification is data compiled by the distribution companies (OLADE and IDB 2016).[3] The reporting method used can account for slight differences in the resulting figures. The results of OLADE, which has taken both methods into consideration, show that, with the exception of Haiti, electrification rates are generally quite high in the LAC region. Even so, a total of 26 million people in LAC still lacked electricity in 2015. Most of those still without electricity live in rural areas, while some reside in urban slums.

Over the last four decades, most countries in the LAC region have come a long way in developing programs for promoting electricity access (figure 2-1). Between 1970 and 2016, coverage grew from levels of about 50 percent to more than 90 percent (OLADE and IDB 2016), mainly owing to government commitment to providing electricity to rural areas without service. For example, Peru's program, which started from quite low rates of rural electrification in 2006, improved to over 70 percent by 2013 with the support of significant government and international investments (box 2-1).

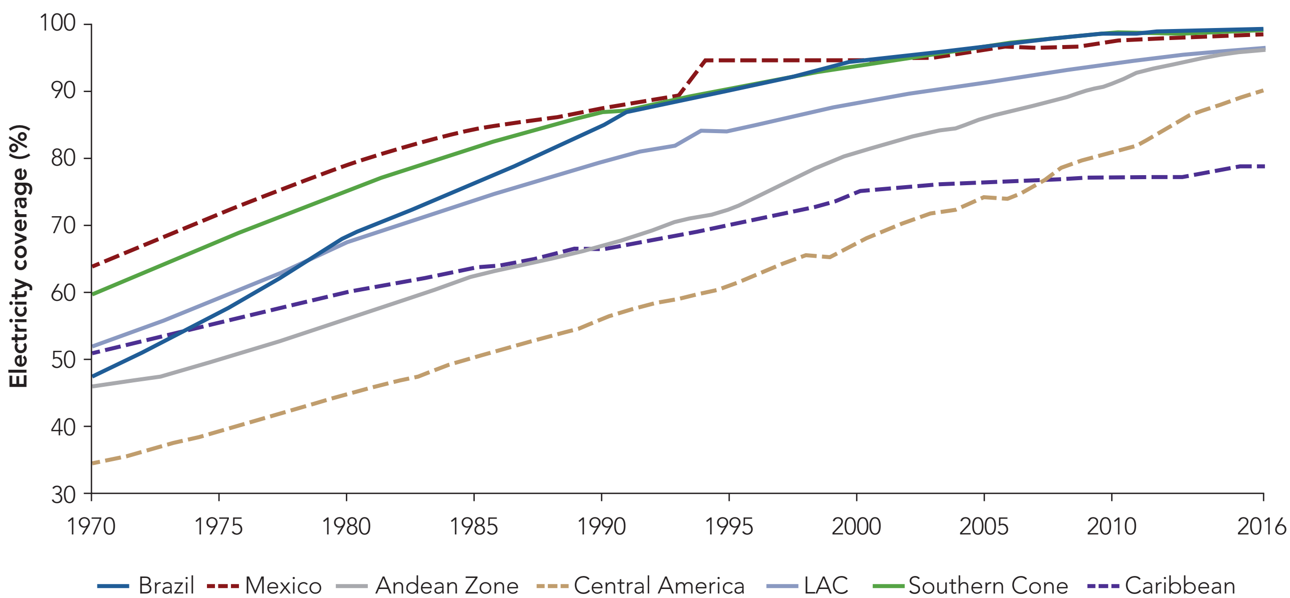
3. OLADE uses both survey and electricity company data to calculate the rates of electrification for each country. This method differs slightly from others, discussed in chapter 3, which based rates mainly on census and household surveys. Utility records can sometimes be inaccurate due to reporting errors and lack of information on household electrification from renewable energy sources, including purchased solar home systems (SHSs).

Table 2-1. Electricity access in LAC countries, 2016

Country	Electricity coverage (%)	Country	Electricity coverage (%)
Argentina	98.8	Guyana	88.2
Barbados	99.8	Haiti	30.0
Belize	93.0	Honduras	75.1
Bolivia	88.0	Jamaica	98.0
Brazil	99.3	Mexico	98.6
Chile	99.7	Nicaragua	90.1
Colombia	97.0	Panama	92.4
Costa Rica	99.3	Paraguay	99.1
Cuba	99.6	Peru	95.1
Dominican Republic	97.1	Suriname	90.3
Ecuador	97.2	Trinidad & Tobago	98.0
El Salvador	96.0	Uruguay	99.7
Grenada	98.1	Venezuela	98.9
Guatemala	92.1		

Source: OLADE 2017.
Note: The figures represent electricity access provided by grid-based systems.

Figure 2-1. Electricity coverage evolution in LAC and subregions, 1970–2016



Source: OLADE 2017.

Box 2-1. Rural Electrification Progress in Peru, 2006–13

Peru, South America's fourth largest country, has a stable government and favorable rates of economic growth. However, like many other LAC countries, it has high rates of inequality and pervasive poverty in rural areas. In 2012, rural levels of poverty averaged 56 percent, compared to national rates of 26 percent. This disparity has been caused, in part, by past low levels of rural infrastructure investment.

In 2005, Peru's rural electrification rate was one of the lowest in the LAC region, at just 30 percent. The government recognized that this issue affected quality of life and economic development opportunities. In response, its National Plan for Rural Electrification (PNER) set a goal of increasing the rural electrification rate to 75 percent by 2013. Financing for this ambitious project was estimated at about US$860 million.

As part of this effort, the Peruvian government initiated the Peru Rural Electrification Project in 2006, with US$50 million in World Bank financing. The project aimed to increase access to efficient and sustainable electricity services and improve quality of life in rural areas. It provided 105,000 new electricity connections, 7,000 of which were from renewable energy sources. Under the project, the number of enterprises adopting electricity to power equipment increased by more than 21,000. With the help of this and other projects, Peru achieved its 75 percent rate of rural electrification goal in 2015.

Source: World Bank 2015b.

Some LAC countries and subregions have performed better than others. As of 2016, five countries in the region had electrification rates of 99 percent or greater. Coverage rates for the Southern Cone and Andean zone were at 99 percent and 96 percent, respectively, while that of Central America was somewhat lower, at 90 percent. Notably, the Caribbean lagged behind the other subregions that year, with a coverage rate of just 79 percent, in part, because of the extremely low levels of electricity access in Haiti.

Biomass Use for Cooking

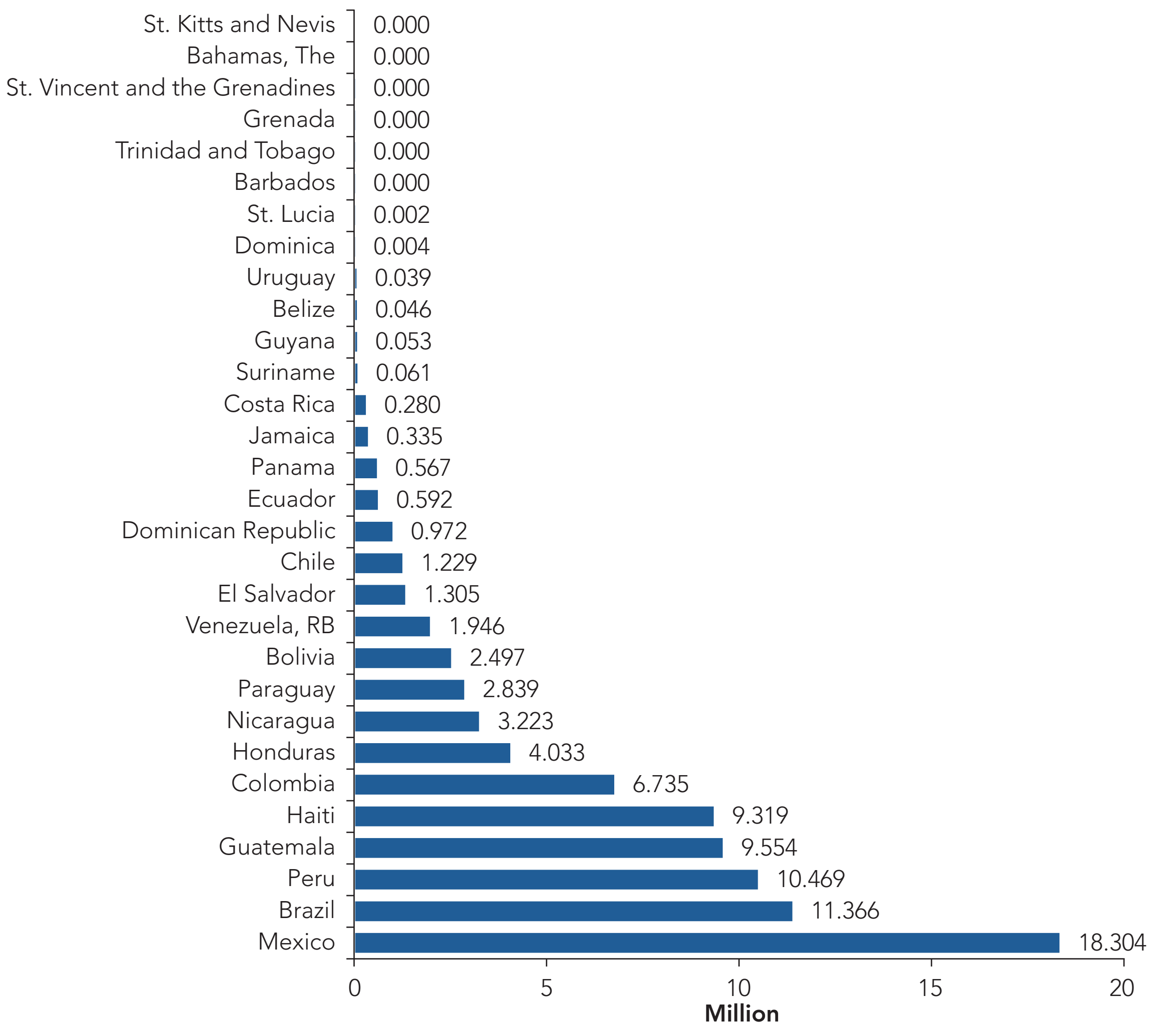
Unfortunately, many people in developing countries still meet their household cooking needs by burning biomass on open fires and primitive stoves, which are quite inefficient at converting energy into heat for cooking. The amount of biomass fuel needed each year for basic cooking can reach up to 2 tons per family, with fuel collection taking up to an hour per day. In addition, open fires and primitive cookstoves emit massive amounts of small particulates in the form of smoke, which fills the home with pollution. Furthermore, where demand for local biomass energy outstrips natural regrowth of local resources, environmental problems can result. Moreover, there is evidence that biomass fuels burned in traditional ways contribute to a buildup of greenhouse gases (GHGs) (Venkataraman et al. 2010). Black carbon or soot emitted from traditional stoves may also have adverse environmental impacts (Ramanathan and Carmichael 2008).

Progress on clean cooking has been minimal: In 2016, more than 2.8 billon people—about the same number as in the year 2000—still cooked on traditional, fuel-inefficient biomass stoves (IEA 2017). Most of the world's rural people depend on fuelwood for cooking simply because other fuels are not available. Commercial cooking fuels and the high initial costs of purchasing stoves and related equipment are sometimes beyond reach for poor households. However, many countries have a large commercial market for supplying biomass fuels, which involves growth of diverse types of vegetation, forestland conversion, various types of logging, charcoal production, urban fuelwood distribution, and fuelwood collection in rural areas (Rivas 2001).

Indoor air pollution (IAP), resulting from the use of rudimentary, fuel-inefficient stoves, has been linked to a range of adverse health effects, the most serious of which are chronic and acute respiratory illnesses (e.g., bronchitis and pneumonia). Women and young children, who tend to spend more hours indoors, are especially vulnerable. About 3 billion of the world's poorest people still rely on solid fuels (e.g., wood, animal dung, charcoal, crop wastes, and coal) for cooking and heating using fuel-inefficient, polluting stoves. The result is an estimated 4 million premature deaths each year from respiratory and cardiovascular diseases and cancer among children and adults (WHO 2014).

In the LAC region, some 80 million people still rely on solid biomass fuels—mainly firewood and charcoal—for cooking (figure 2-2). While the percentage of people without access to clean cooking fuels has been on the

Figure 2-2. Access to modern cooking fuels and access deficit in LAC, 2014 (millions of people using solid fuels for cooking)



Source: World Bank 2014.
Note: Figures may differ slightly from those in table 2-2 due to inclusion of Mexico and difference in reporting years.

decline, some countries still have portions of their populations relying on biomass fuels. In Haiti, for example, more than 90 percent of people depend on biomass—including a large amount of charcoal—for cooking. In some other LAC countries, the percentage of the population without access to clean cooking is also quite high by developed country standards. These countries include Guatemala (30 percent), Nicaragua (52 percent), Honduras (52 percent), Paraguay (33 percent), and Peru (32 percent) (table 2-2).

As of 2014, countries with large populations also tended to have high numbers of people dependent on biomass fuels for cooking. Mexico had the most, at 18.3 million, followed by Brazil (11.4 million), Peru (10.5 million), Guatemala (9.6 million), and Haiti (9.3 million)

Table 2-2. Households without access to clean cooking, LAC, 2000–15

	People without access to clean cooking (%)				Population without access (millions)	Population relying on biomass (millions)
Region or country	**2000**	**2005**	**2010**	**2015**	**2015**	**2015**
Central and South America	19	18	15	12	59	57
Argentina	5	4	3	—	—	—
Bolivia	33	30	19	17	2	2
Brazil	12	10	7	5	10	10
Colombia	20	18	14	13	6	6
Costa Rica	13	9	8	6	< 1	< 1
Cuba	9	9	9	6	< 1	< 1
Dominican Republic	14	14	15	12	1	< 1
Ecuador	2	7	7	6	< 1	< 1
El Salvador	27	27	23	20	1	1
Guatemala	57	57	45	30	5	5
Haiti	> 95	> 95	94	93	10	10
Honduras	68	58	54	52	4	4
Jamaica	16	15	14	13	< 1	< 1
Nicaragua	62	60	55	52	3	3
Panama	19	17	16	14	< 1	< 1
Paraguay	55	51	43	33	2	2
Peru	46	42	36	32	10	10
Trinidad and Tobago	1	1	1	1	< 1	< 1
Uruguay	2	4	3	1	< 1	< 1
Venezuela	3	2	2	2	< 1	< 1
Other Central and South America	**19**	**15**	**13**	**13**	**< 1**	**< 1**

Source: IEA, Energy Access Outlook 2017.

(figure 2-2). In the large countries, many of the households that rely on biomass for cooking live in fairly remote rural areas.

Last Mile Problems

Most of LAC's rural electrification programs are at an advanced stage, with electricity coverage rates above 90 percent. For projects and programs in remote rural areas that still lack electricity access, it is important to take customer affordability and the utilities' financial viability into account. Without incentives for households, private companies cannot provide energy services without experiencing significant losses. Even after adopting electricity, most low-income rural households will consume only meager amounts of electricity. Rural areas' comparatively low levels of electricity demand can be a disincentive for utilities to extend the power grid. Another disincentive for providers is that rural customers tend to be widely scattered; the small number of customers per kilometer of electricity line means lower revenues as a percentage of investment costs.

Given the high cost of extending grid-based systems to reach last-mile, rural households, viable solutions will include a combination of grid electricity, community micro-grids, and individual home systems. Even in the case of solar home systems (SHSs), thin markets mean that reaching out to customers is expensive. Thus, electricity service providers will need incentives to reach customers in increasingly remote areas. If rural customers can have electricity service that is affordable and reliable, then greater numbers of people will adopt and use electricity. This, in turn, will increase the attractiveness of such areas for service providers selling electricity.

One exception to the last mile problem in LAC is the country of Haiti. Unlike most other countries in the region, Haiti has extremely low levels of electricity access, at only about 30 percent. Admittedly, institutional issues in Haiti have prevented the provision of electricity at rates that are common for the rest of the region. However, Haiti's high population densities suggest that the task of extending electricity may be less financially taxing than in many other LAC countries. Therefore, priority should be given to surmounting some of the financial and institutional barriers that are keeping electricity access levels low in that country (box 2-2).

Addressing the low rates of electricity access in Haiti and the last-mile electricity access issues in the rest of LAC will not be easy. For decentralized systems, some

Box 2-2. Low Institutional Capacity to Increase Energy Access in Haiti

After the 2010 earthquake in Haiti, the World Bank's Rebuilding Energy Infrastructure and Access Project, initiated in 2012, aimed to strengthen the capacity of the electricity company serving Haiti, reconstruct the electricity system damaged by the earthquake, connect new customers, and improve off-grid connections using solar energy and local systems. This project has partially succeeded in improving dialogue between international agencies and the government. In poor areas, more than 500 solar streetlights have been installed, and four power distribution systems in Port-au-Prince have been rehabilitated.

Unfortunately, financing disbursement is far behind schedule, with only 10 percent of connection targets having been achieved. Only half of the households that lost electricity due the earthquake have had their power restored. In the short term, improving energy access will continue to be difficult. However, progress is being made in strengthening Haiti's electricity company, and investments in institutional capacity building may have beneficial results in the long run.

Source: World Bank 2016a.

type of subsidy will be necessary to make electricity affordable for low-income customers in remote rural areas. In many parts of LAC, numerous innovative projects and programs are already in place, and lessons learned from these efforts will be essential to moving forward. Because electricity is not a free service, it is important that LAC follow well-established guidelines for the development of rural electrification. The main ones include policies to maximize the benefits for local communities and identify barriers to electricity adoption, including such factors as high connection costs. It is also important to establish an appropriate climate for private-sector participation in providing rural energy services.

To reach their full development potential, electricity programs also require investments in complementary infrastructure and services (e.g., health and education). Electricity by itself does not lead to economic transformation. Its development impact is greater in conjunction with—not in isolation from—other development programs. Such an integrated approach is likely to generate new opportunities for productive an d commercial activities. In this situation, electricity distribution and energy service companies promoting renewable energy–based isolated systems will have greater financial benefits resulting from expanded demand for electricity.

Chapter 3

Approaches to Monitoring Energy Access in Developing Countries

The term *energy poverty* is a way to conceptualize the lack of access to modern energy by vast numbers of the world's people. It is also a way to develop awareness of energy problems as they relate to households and provoke actions aimed at their solution. Earlier on, the concept of a "fuelwood crisis" was linked to a pending cooking fuel shortage for much of the developing world's population (Eckholm 1975; Barnes 1990). A common way to describe the energy poor is to refer to them as the 2.8 billion people who depend on solid fuels for cooking and heating and the slightly more than 1 billion people without electricity. Although this description is useful on a global scale, no consensus for measuring energy poverty has been reached at a national or community level.

The concept of a poverty line encompasses a large body of literature on how to measure income or expenditure poverty (Ravallion 1998; Ravallion and Bidani 1994; Pradhan and Ravallion 1998; Haughton and Khandker 2009). However, there is no similar consensus for measuring energy poverty. International and government agencies use various definitions and approaches to track energy poverty. This chapter reviews the main approaches used to provide a framework for viewing energy poverty.

Energy Poverty Indices

Traditionally, the energy sector has not been given significant weight in national plans for poverty reduction and development. The reason is that electricity is important for all sectors, whether power pumps for water supply or lighting schools for education. For the more than 23 million people in the LAC region that lack electricity access, a home without electricity used for at least lighting services would be a partial indicator of poverty (OLADE 2017). In addition, some 80 million people in LAC satisfy their basic cooking needs with mainly primitive technologies fueled by wood, charcoal, agricultural residues, and animal dung (World Bank 2013). Such fuels can be harmful to both human health and the environment. Many households still use open fires for cooking and heating in stoves that differ little from those used by our distant ancestors.[4]

The relationship between energy, poverty, and development is considered an important policy issue (Beljansky 2014; Nussbaumer 2012; Halff, Sovacool, and Rozhon 2014; Shrestha and Acharya 2015; Ochoa 2014). A joint study by the International Energy Agency (IEA), the United Nations Development Programme (UNDP), and the United Nations Industrial Development Organization (UNIDO) indicates that the lack of access to modern energy services is a serious obstacle to socioeconomic

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

development (IEA, UNDP, and UNIDO 2010). The relationship between income and access to modern energy services is described by international agencies as "essential for the provision of clean water, sanitation and health care and provides great benefits to development through the provision of reliable and efficient lighting, heating, cooking, mechanical power, and telecommunication and transport services." (UNIDO 2010).

Defining energy poverty in developing countries has been approached in various ways.[5] Some definitions include only essential uses (e.g., cooking and lighting), while others encompass a wider range of services and productive uses. One common approach has been to define an energy poverty line as the income point below which energy use and/or expenditures remain the same, implying that this is the bare minimum energy needs (Barnes 2010a). The goal is to develop policies and programs to lift people out of energy poverty. This is more of a demand-based approach, which uses surveys to define the point at which households use a minimum amount of energy necessary for sustaining life.

A second approach compiles energy indicators at the country level. This effort is led by the Energy Development Agency and the indicator is called the Energy Development Index (EDI). Household, public service, and productive use of energy are combined into one index that is meant to rank countries, and there is no cutoff point that defines energy poverty.

A third approach is to classify households according to multiple indicators of their use of modern energy services. This approach attempts to measure energy development mostly at the country level, using such indicators as availability of electricity in households and types of cooking fuels used by households. The idea is to capture the multidimensionality of energy use for measures that can be monitored and tracked at the country level. The following sections review the three main approaches in detail, while a final section focuses on the constraints of national surveys to provide quality energy consumption data.

5. In developing countries, the energy poverty discussion includes an access dimension. But in Europe, energy poverty is widely discussed in terms of affordability since all household have access to energy. Such discussions recognize that the poor have energy access, but simply cannot afford to purchase sufficient amounts of energy to meet their basic needs.

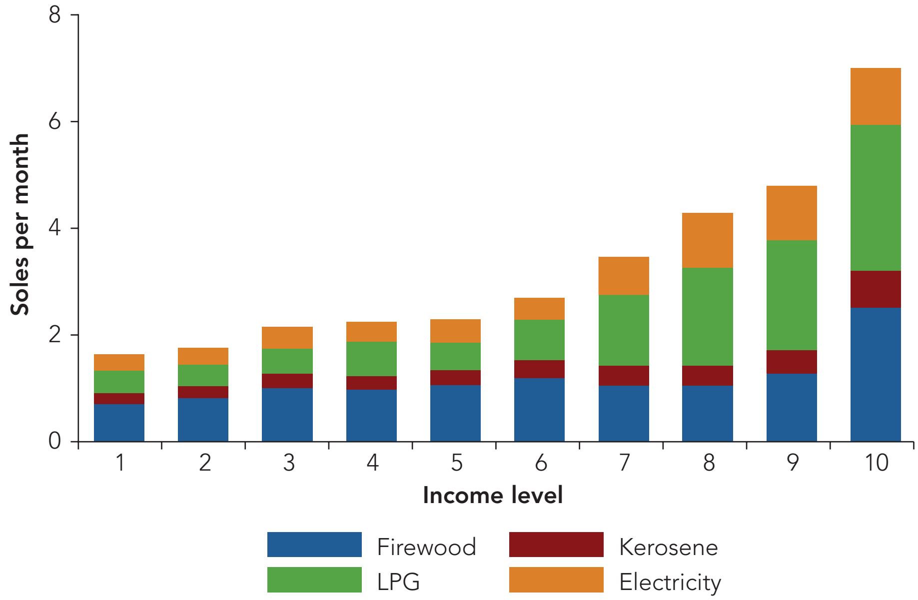
Energy Poverty Defined as Minimum Need for Energy

Many approaches to defining energy poverty rely on statistics from energy suppliers, often ignoring the demand side. A more demand-oriented approach to energy poverty is based on the minimum energy consumption determined by income, after controlling for a variety of exogenous household and socioeconomic factors (Barnes, Khandker, and Samad 2011). This approach defines energy poverty as having energy consumption below a threshold amount that is insensitive to household income, which occurs mostly for lower-income households. This is not to imply that energy consumption is insensitive to income as a whole. Rather, it is based on minimum amounts of energy consumption for a portion of low-income households.

This method can be illustrated by an analysis of energy expenditures in rural Peru. For the higher-income groups (the sixth through the tenth income levels), energy consumption increases significantly, and the energy mix changes with greater use of electricity and LPG. These same fuels are used by households in lower-income groups, but, owing to limited incomes, they use them sparingly. Most households also use firewood. Similar amounts of energy are used by lower-income groups, identifying this level as the bare minimum need (figure 3-1).

The motivation behind this poverty line approach is that, while energy consumption is generally expected to rise with household income, this rise is not uniform. At the lower end of the income profile, energy consumption does not immediately go up as incomes rise, instead remaining relatively flat. The reason is that households at and below that income threshold consume, on average, only the bare minimum amount of energy needed to sustain themselves. That is, there is a level of income

Figure 3-1. Total energy expenditure per capita by source in rural Peru, 2006



Sources: Data from the Government of Peru, 2010, and National Survey of Rural Household Energy Use, 2006.
Note: Exchange rate is 3.23 Soles per US dollar.

below which energy consumption remains constant, and this level of consumption corresponds to the absolute minimum energy necessary for meeting basic needs for cooking and lighting, given the socioeconomic context that the data belong to. The objective of this approach is to determine that energy consumption threshold against which to compare the actual consumption of households.

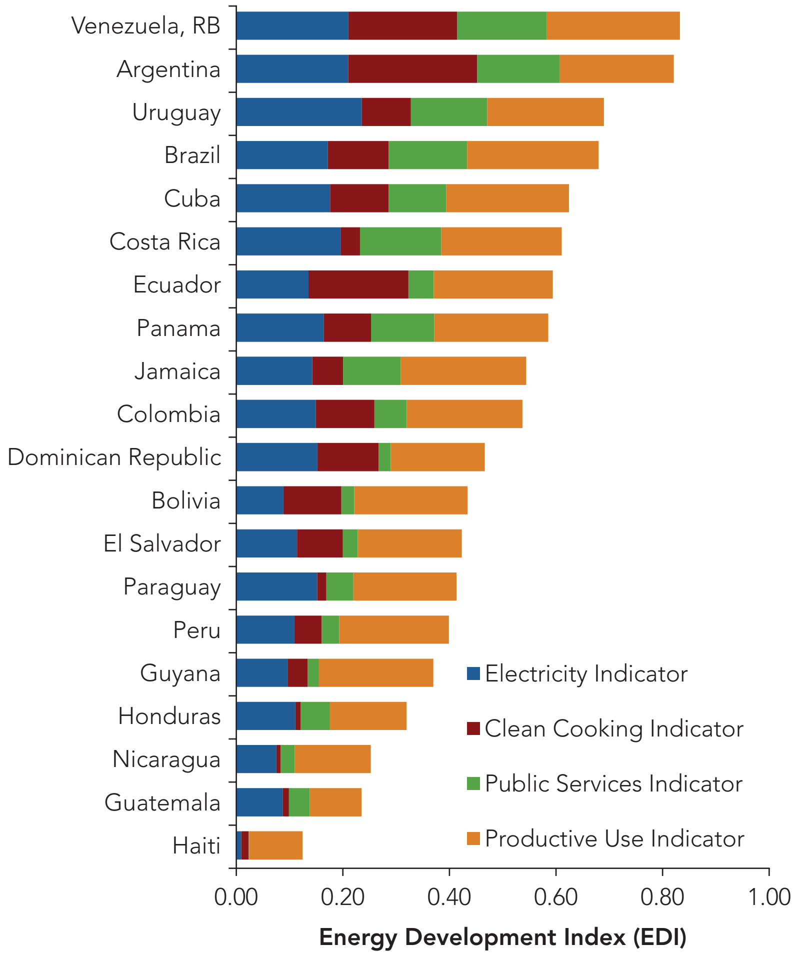
Energy Development Index Defined as Lack of Access

The International Energy Agency (IEA) measures a country's access to reliable energy services using a multidimensional indicator, known as the Energy Development Index (EDI). This indicator tracks energy development by country, distinguishing between degree of development in households and communities. In households, access to clean cookstoves is considered, along with a minimum level of electricity usage. The amount of minimum electricity use in the index also increases over time. At the community level, the access indicator includes the modern use of energy for public services (e.g., schools, hospitals and clinics, water and sanitation systems, and public lighting) and productive uses.

The EDI monitors the measurement of changes in energy access. For example, the electricity access indicator is a combination of the percent of the population with access to electricity and the per capita residential electricity consumption. The measures are combined to create a multidimensional indicator. Similarly, other aspects of modern energy, including cooking, are combined to form a consolidated score that defines the EDI.[6] The IEA's EDI database presents detailed results for 80 countries, including many in LAC (table 3-1). For each index, a score of either 0 or 1 is given, based on the level of energy service. Subsequently, a simple average is calculated for a country's EDI. The relative position of countries ranges from a low of 0.04 (Ethiopia) to a high of 0.92 (Libya).

6. The definitions and calculation process for various indices used in measuring the EDI can be found at www.worldenergyoutlook.org.

Figure 3-2. Energy development indicators in LAC, 2010

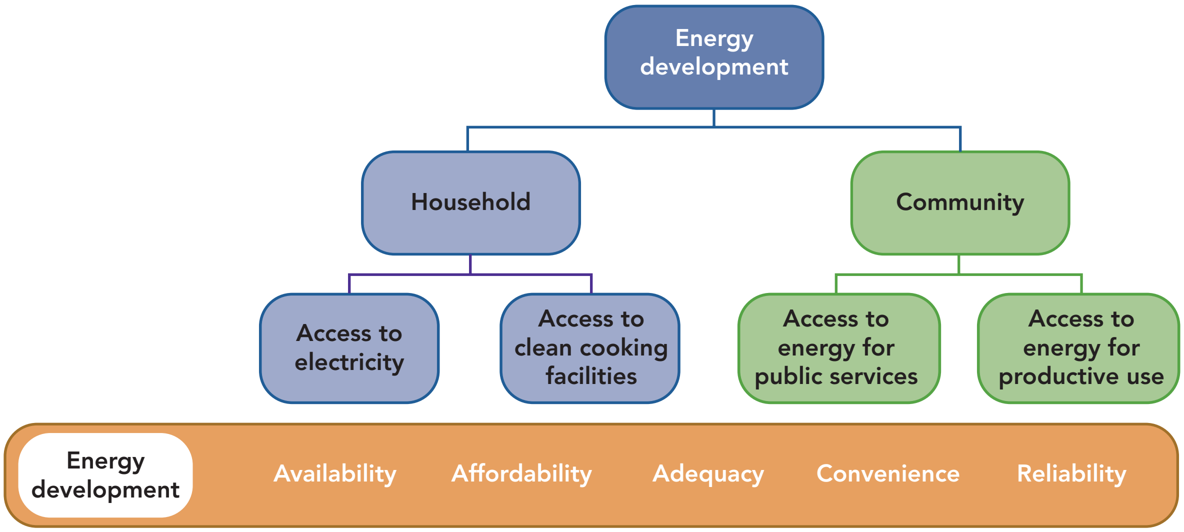


Source: IEA 2012.
Note: The IEA last updated the EDI in 2012 for 2010 data.

The EDI ratings for most LAC countries are fairly high. One reason is that countries in LAC (e.g., Venezuela and Argentina) allocate considerable budget resources to promote modern energy adoption. As expected, the energy poverty rates of Haiti, Guatemala, and Nicaragua are quite high (figure 3-2) (Annex).

The IEA's *World Energy Outlook* bases its energy access indicator on households having affordable and reliable access to a minimum level of electricity consumption and clean cooking facilities that improve over time (IEA 2014; 2017). The IEA considers the minimum monthly amounts of electricity necessary for not being energy poor as 250 kWh for rural households and 500 kWh for urban households. For cooking, the index is calculated based on access to high-quality fuels, such as LPG, and modern biomass stoves capable of dramatic reductions in emissions. The IEA is also participating in the Global Tracking Framework (GTF). In response to concerns that its indicator was too narrow, the IEA has attempted to link access to energy services to overall energy development by expanding the measurement to the community level. This includes measuring energy access for public enterprises and productive uses (figure 3-3).

Figure 3-3. Linking the EDI to energy access



Source: IEA 2012.

The characteristics of energy supply quality have also been incorporated into the IEA's index. For any energy supply to provide a genuine opportunity to use modern energy services, there must be availability, affordability, and adequate supply. The energy service should be safe to use and available during desired hours of the day (IEA 2014). The EDI assesses the conditions of energy services access for a particular country, but unfortunately does not describe those conditions for a country's specific regions or areas. Because of this limitation, the EDI is not useful for developing interventions in specific regions, as is usual in rural electrification plans or other energy development strategies.

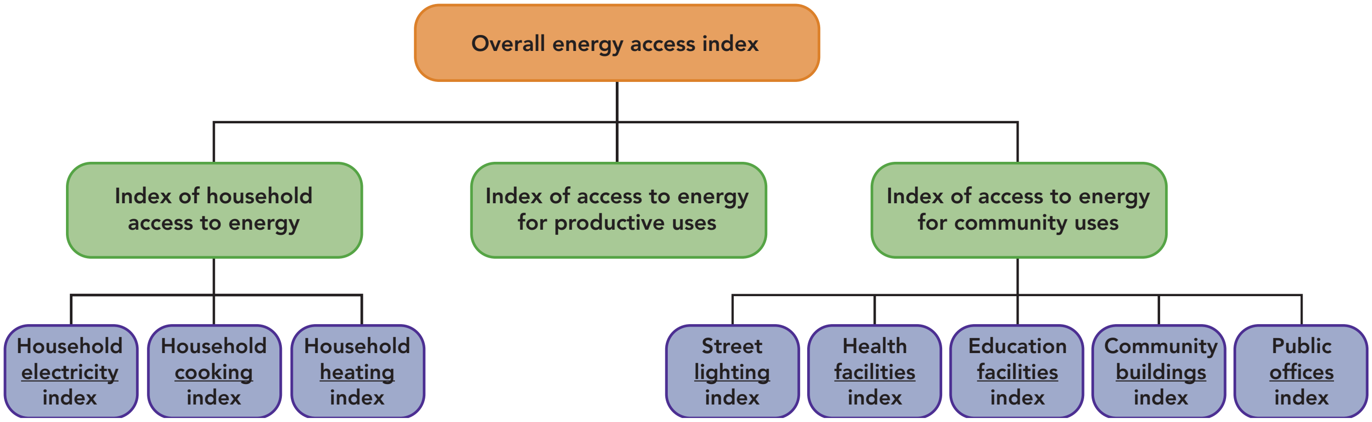
Global Tracking Framework and Tiers of Energy Poverty

The GTF's approach goes beyond the idea of simple energy access by defining tiers of energy poverty. In this way, the approach measures quality of energy service, as well as access; that is, people must have energy supply that is both reliable and of good quality. In addition, energy should be convenient and safe to use and not harmful to health. The Multitier Framework includes household, productive, and community uses of energy (World Bank 2015a, 2016b).[7] To capture the multidimensionality of energy access, indicators of energy use by households and communities and for productive activities are included (figure 3-4).

Compared to previous attempts to measure energy access, the GTF is more ambitious because it requires standardized surveys in order to collect widely disaggregated data. These are undated, national surveys with questions on energy access and use. The availability of better data makes it possible to more accurately measure energy access. At present, data from surveys in 12 countries (including one in Honduras) are being collected and will be analyzed to generate a diagnostic and series of energy access indicators, which could then be used to estimate an overall energy access indicator (World Bank 2016b).

7. The GTF includes cooking in its identification of challenges to defining and measuring access to modern energy services. The IEA distinguishes between fuels used in stoves for cooking. It is the combination of stove and fuel use that determines levels of efficiency, pollution, and safety (IEA 2015b).

Figure 3-4. Indicators of energy access for households, businesses, and community institutions



Source: ESMAP 2015.

According to the GTF, information on the energy supply chain is also necessary for capturing the multidimensionality of energy services access (IEA 2015b; IEA and the World Bank 2017). For example, the quality of electricity supplied has important implications for the impact of energy for development. This indicator might include the peak capacity available to a household or business, duration and time of supply, voltage quality, connection legality, and affordability involving tiers of energy access.

A wide array of technologies and appliances (e.g., television, radio, lamps, rechargeable cell phones, air conditioners and heaters, water pumps, computers, microwave ovens, washing machines, irons, and electric stoves), along with the availability of electricity connections by level of service, is also important for the multitier index. This classification is shown as a matrix to measure access to services that electricity can deliver to households through the use of various technologies, as well as the equipment required for electricity supply (table 3-1) (IEA and the World Bank 2015).

In order to capture the full multidimensionality of energy access for cooking, the GTF team has defined a two-step process: (i) performance of the technology used for cooking and (ii) the technology's characteristics and actual use conditions. Cookstove levels are classified from grade A (best technology) to grade E (poor technology).

In 2012, an international workshop at The Hague, including more than 90 experts from 23 participating countries, sought to reach an agreement on defining international standards for clean cookstoves. The goal was to identify measures important for defining a clean cookstove. A guide developed at the workshop assesses cookstove performance standards based on four performance indicators: (i) thermal efficiency of stoves, (ii) emissions of fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO) into the kitchen area, (iii) general emissions released into the community, and (iv) safe use of cookstoves. These measures involve scientific studies performed in both the field and laboratories.

The quantification of performance standards for cookstoves includes four indicators: (i) efficiency, (ii) indoor pollution, (iii) overall pollution, and (iv) safety. These indicators are classified according to five tiers, which are equivalent to technology grades (A–E). The tiers range from 0 (the lowest level), equivalent to an open fire or three-stone stove, to 4 (the highest level), equivalent to LPG. The desired goal is to reach tier 4, which is based on guidelines issued by the World Health Organization (WHO). With each higher tier, the degree

Table 3-1. Matrix for measuring access to electricity services at the household level

Attributes		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Peak capacity	Power		Very low power, minimum 3 watts	Low power, minimum 50 watts	Medium power, minimum 200 watts	High power, minimum 800 watts	Very high power, minimum 2 kilowatts
	and Daily capacity		Minimum 12 watt-hours	Minimum 200 watt-hours	Minimum 1.0 kilowatt-hours	Minimum 3.4 kilowatt-hours	Minimum 8.2 kilowatt-hours
	or Services		Lighting of 1,000 lumen-hours per day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Minimum 4 hours	Minimum 4 hours	Minimum 8 hours	Minimum 16 hours	Minimum 23 hours
	Hours per evening		Minimum 1 hour	Minimum 2 hours	Minimum 3 hours	Minimum 4 hours	Minimum 4 hours
3. Affordability					Cost of a standard consumption package of 365 kilowatt-hours per annum is less than 5 percent of household income		
4. Reliability						Maximum 14 distributions per week	Maximum 3 disruptions per week of total duration less than 2 hours
5. Legality						Bill is paid to the utility/ prepaid card seller/authorized representative	
6. Health and safety						Absence of past accidents/ no perception of high risk in the future	
7. Quality						Voltage problems do not affect use of desired appliances	

Source: IEA and the World Bank 2015.

of stove users' exposure to harmful pollution decreases, while efficiency and safety increase (Ekouevi, Freeman, and Soni 2014) (table 3-2).

For the multitier index, efficiency of the actual stove is only the first step in measuring clean cooking. The second step involves the actual use of cookstoves in terms of three attributes important for estimating access to modern cooking solutions: (i) conformity, (ii) convenience, and (iii) adequacy. The conformity indicator measures the household's proper use of the cookstove, chimney, hood, or skirted pot. This aspect also includes

Table 3-2. Tier-based performance standards for cookstoves

Indicator	Measure	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
Efficiency	HPTE (percent)	< 15	> 15	> 25	> 35	> 45
	LPSC (MJ/min/L)	> 0.05	< 0.05	< 0.039	< 0.028	< 0.017
Indoor pollution	CO (g/min)	> 0.97	< 0.97	< 0.62	< 0.49	< 0.42
	PM (mg/min)	> 40	< 40	< 17	< 8	< 2
Overall pollution	HPCO (g/MLd)	> 16	< 16	< 11	< 9	< 8
	LPCO (g/min/L)	> 0.2	< 0.2	< 0.13	< 0.1	< 0.09
	HPPM (mg/MJd)	> 979	< 979	< 386	< 168	< 41
	LPPM (mg/min/L)	> 8	< 8	< 4	< 2	< 1
Safety	Iowa protocol	< 45	> 45	> 75	> 88	> 95

Source: World Bank 2013.
Note: HPTE = high power thermal efficiency; LPSC = low power specific consumption; CO = carbon monoxide; PM = particulate matter; HPCO = CO (in grams per megajoule delivered to the pot) at high power, i.e., operation of the stove at or near the maximum rate of energy use; LPCO = CO in grams per minute per liter at low power, i.e., operation of the stove at or near the minimum rate of energy use; HPPM = PM in milligrams per megajoule delivered to the pot at high power; LPPM = PM in milligrams per minute per liter at low power.

whether stove cleaning and maintenance are performed regularly. The convenience indicator considers the time it takes for the household to collect fuel and prepare the fire. Finally, the adequacy indicator considers whether the household must use a secondary stove for cooking. This situation may occur if the primary fuel is too expensive or is not always available (e.g., households that run out of LPG must resort to a backup stove). In addition, the stove may not be suitable for cooking certain types of dishes or perhaps lacks the desired number of burners. If use of the primary cookstove is limited by such factors, then it is considered inadequate. Thus, in addition to the stove's technical performance for cooking, the access indicator of the Multitier Framework attempts to assess its impact on users' daily lives.[8]

8. Based on a collaborative effort of the IEA and World Bank, the Multitier Framework has yielded a much more complex indicator for measuring energy access than has the IEA's simpler EDI approach. Development of the more complex approach suggests the need for better information from national surveys to classify countries according to their access to quality energy services.

National Survey Constraints for Measuring Energy Access

Data limitations are an issue for all approaches to measuring energy access and energy poverty. Currently, most national surveys include only a few questions related to energy access (e.g., whether a household has electricity, the type of lighting used, and the main type of cooking fuel). The lack of standardized national surveys with more detailed questions on energy access, especially for poor communities, hinders the development of sound measures of energy access and energy poverty.

The IEA and OLADE have assembled energy access indicators obtained from survey and census data. The World Bank, the IDB, and other international organizations have energy information systems in place to extract data from available public statistics. Recently, the World Bank has added questions to national surveys as part of its effort to better quantify the Multitier Framework for defining energy access (World Bank 2015a, IEA and the World Bank 2017). The WHO's Global Health

Observatory has focused on measuring access to domestic cooking fuels and various types of stoves; however, its health surveys have very few questions on energy access.

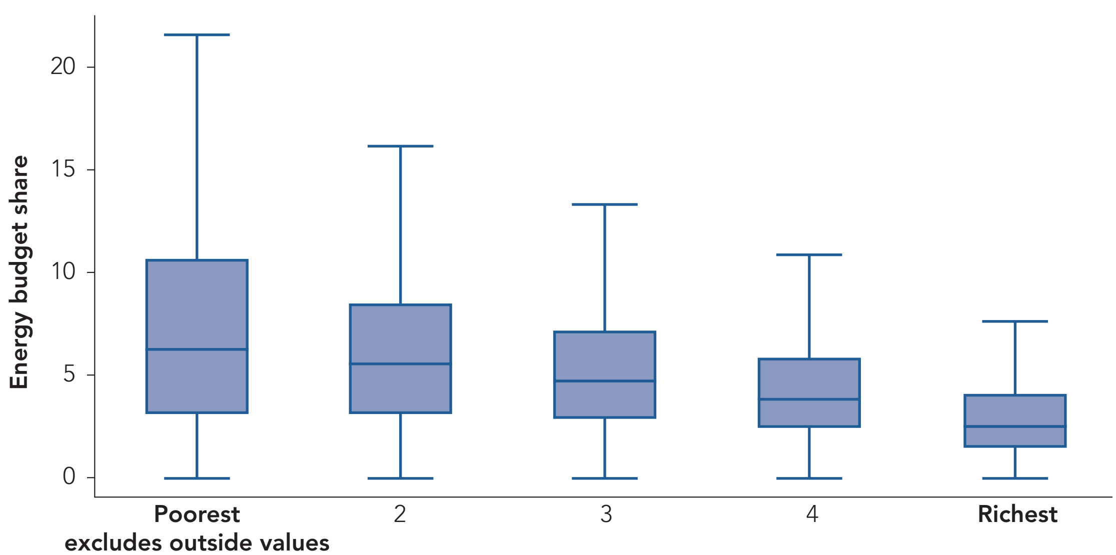
Most international poverty or household budget surveys have a limited set of energy questions (commonly in a "yes/no" format). This is somewhat surprising, given that energy represents 5–20 percent of household income. These findings were common in such diverse countries as Peru (Meier et al. 2010), India (World Bank 2002a), Philippines (World Bank 2002b), and Bangladesh (Khandker, Barnes, and Samad 2012. In a recent study of national budget surveys in 13 countries of LAC spanning the last 15 years, it has been found that energy expenditures for poor households are quite wide-ranging, averaging about 7 percent; however, in extreme cases, they reach over 30 percent (figure 3-5).

Most existing surveys lack sufficient questions on energy access and use. For example, in most budget surveys, such as those cited in figure 3-5, the expenditures of time—and sometimes even money on firewood—are not collected to reflect the true costs to households. Also, the survey questions do not assess the efficiency of energy services and related impacts on the environment. In addition, they do not measure the quality, reliability, safety, or sustainability of energy services. Generally, there are no questions on past patterns of energy use. Furthermore, they lack the variables necessary to explore the relationships between energy and other aspects of sustainable development.

Complicating the task of collecting quality information important for an energy index is that international organizations have not agreed on a single definition of access to modern energy services. That said, their definitions do include similarities, as follows:

- A minimum level of electricity for households;
- Safer and sustainable cookstoves that, combined with fuels, have minimal harmful effects on health and the environment;

Figure 3-5. Energy expenditures as a percent of income in 13 LAC countries, 2014



Source: Jimenez and Yepez-Garcia 2017.
Note: The countries include Bolivia, Brazil, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, Peru, and Uruguay. The surveys contain information on transportation fuel expenses that are not typically part of household energy surveys in most countries. This has an impact on the expenditures of high-income households, but typically little on those of the poorest households. The survey years vary significantly, and the data has been normalized to the year 2014.

- Access to modern energy that allows for productive economic activity, including mechanical energy for agriculture, textiles, and other industries; and
- Access to modern energy by public services and facilities (e.g., street lighting, health centers, and schools) to better serve communities.

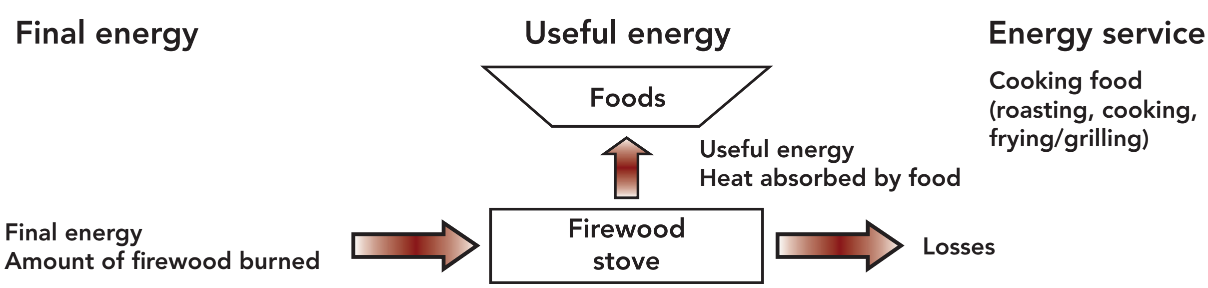
Accepted concepts and definitions are necessary to evaluate whether the energy services provided by various fuels and technologies are adequate. These definitions must also be complemented by the user's perspective. In order to encourage greater use of modern energy, international organizations must understand how consumers make decisions when choosing types of fuels and appliances. No doubt, decision making is based on the local availability of energy resources, appliances, and machines available for purchase. In addition, households make choices based on cost, convenience, and social acceptability of appliances. The most common uses of modern energy, even by poor households, include lighting, space conditioning (heating and cooking), cooking, and mechanical power.

Energy services are defined as the final stage of energy provision (Modi et al. 2006). Supply chains are depicted somewhat differently, incorporating the concept of energy flow or energy balance. The term *final energy* is the amount of energy consumed, regardless of the efficiencies of equipment or consumer devices. This includes energy lost in the last transformation of the supply chain. *Useful energy* is the amount of energy actually used to meet production or service functions of equipment or consumer devices (e.g., electricity used to power a fan). In the context of cooking, final energy is the total amount of wood or other solid fuels that are burned, while useful energy is only that amount of energy necessary for a task (e.g., heat absorbed by the pan). The final energy for cooking is often 3–4 times the amount of useful energy because much heat escapes around the sides of the pan. Energy service is the outcome of the energy used (e.g., cooked food). In the context of space conditioning, energy service might be cooled or warmed air (figure 3-6).

For stoves, it is important that information be based on stove efficiency and pollutants emitted during typical cooking activities. In Peru, for example, stoves in the National Improved Cookstove Campaign recently had to undergo certification before being promoted for use in communities (Wang et al. 2014). A national training institute issued stove certification that met predefined technical specifications. Also, a monitoring system was set up to record the location and efficiency of stoves. This example shows how projects can measure their effectiveness, which is also important for understanding the final energy service provided by wood energy.

As the Multitier Framework stresses, appropriate survey data is necessary in order to classify households according to their level of energy use and monitor the welfare impact of new energy policy or project interventions. A program designed to reduce fuelwood consumption

Figure 3-6. Relationships between final energy, useful energy, and energy services



Source: This study.

and indoor air pollution, for example, can measure changes in energy consumption after households adopt improved cookstoves. Survey data can be used to evaluate changes in household energy consumption when fuel price subsidies are removed or service charges for electricity are raised. With high-quality survey data, the impacts of policy interventions that aim to encourage greater adoption of modern energy services (e.g., lifeline rates, credit financing schemes, or better design standards and technologies) can also be measured. Besides the need for intensive data collection, another problem with the Multitier Framework is that the indicators may not reflect the correct dimensions of energy poverty. They are related more to the quality of energy service, but there is no minimum threshold established to estimate the extent or severity of energy poverty.

Summing up, measuring the impact of energy for development requires fairly detailed surveys. In the past, the benefits of energy were often linked to final or useful energy. Over the last two decades, however, approaches to measuring energy services have aligned themselves more closely with actual energy services and their benefits (e.g., lighting and space conditioning). In fact, the various measures of energy poverty could benefit from understanding how they track the benefits of energy access. Measuring the benefits of energy based on the provision of services is explored in the next chapter.

Chapter 4

Impact Evaluation of Energy Access

Recent years have witnessed growing interest in the concept and measurement of energy access among governments and development agencies, along with increased recognition of impact evaluation—detailing how and to what extent policies and project interventions contribute to socioeconomic welfare gains or losses for society—as an essential component of project development. Impact evaluations are important for identifying key lessons from past projects for future policies and investments. Measuring the cost of investments in physical energy-access infrastructure (e.g., lines, poles, and photovoltaic [PV] systems) is generally straightforward. However, measuring the benefits that such investments produce for society is more difficult, possibly involving the implementation of complex national or regional surveys and complicated statistical techniques. Given the complex pathways of the benefits resulting from providing rural populations and others without modern energy services access to electricity and clean cooking energy, many past projects and programs have underestimated the benefits.

This chapter reviews the two main methods that have been developed to measure the benefits of rural energy services, including both electricity and clean cooking. Both methods involve formal and informal data collection techniques, including quantitative and qualitative analysis. The research considers such concepts as quality of life and effects on education and other key components of social development. That is, it tackles the benefits of modern energy access that traditionally have been difficult to measure, as well as the easier-to-measure ones.

Transition to Modern Energy and Development Pathways

Before turning to the techniques necessary to evaluate the value of energy for development, it is important to understand the rationale for measuring the benefits of modern energy. When households in developing countries begin to adopt electricity and clean cooking methods, a transition from traditional to more modern forms of energy has clearly begun to occur. The terms *traditional* and *modern* refer to both the fuel types and technologies used. For example, *traditional stove* refers to either open fires or stoves constructed by household members or artisans that are not energy efficient and have poor combustion features. *Improved cookstove* is used in the historical sense to refer to stoves installed in so-called legacy programs, which have usually featured a firebox and chimney, but with poor quality control and without standards. *Advanced biomass cookstove* refers to the more recent manufactured stoves, which are based on higher levels of technical research. Generally more expensive, these stoves are based on higher, but as yet not well-defined, standards that include safety, efficiency, emissions, and durability. They might include wood, charcoal, pellet, and gasifier stoves. Modern stoves can burn either biomass or LPG; the idea is that both achieve greater efficiency and reduced levels of air pollution and meet high standards.

The transition from low-quality energy services to more modern ones can take many forms. Depending on how it is burned, wood can be used as a traditional or modern cooking fuel. In a traditional open fire, wood burns quite inefficiently, emitting 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, traditional kerosene lamps emit poor-quality light with low efficiency, while electric lights may emit up to 100 times more light (O'Sullivan and Barnes 2006; Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1998). Electric lighting, which enables households to read, socialize, and be more productive in the evening, has also been associated with children's greater school attendance (Khandker, Barnes, and Samad 2012, 2013). In even the most remote areas, grid electricity and renewable energy sources (e.g., household PV systems, micro hydro–powered mini-grids, and solar pumps) can provide modern energy services, including quality lighting, communication, motive power, and space conditioning (i.e., heating and cooling) (table 4-1).

Table 4-1. Transitions to grid-based and renewable energy in developing countries

Energy service	Traditional off-grid rural energy sources	Examples of modern energy sources
Lighting and other small-scale electricity needs (homes, schools, street lighting, telecom, hand tools, and vaccine storage)	Candles, kerosene, 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 • Solar home systems • Traditional grid electricity systems
Communication (televisions, 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 • Solar home systems • Traditional grid electricity systems
Cooking (homes, 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-grid systems from micro-hydro, gasifiers, direct combustion, and large biodigesters
Water pumping (agriculture and drinking water)	Diesel pumps and generators	• Mechanical wind pumps • Solar PV pumps • Small-grid systems from micro-hydro, gasifiers, direct combustion, and large biodigesters • Grid electricity systems

Source: Barnes 2014.

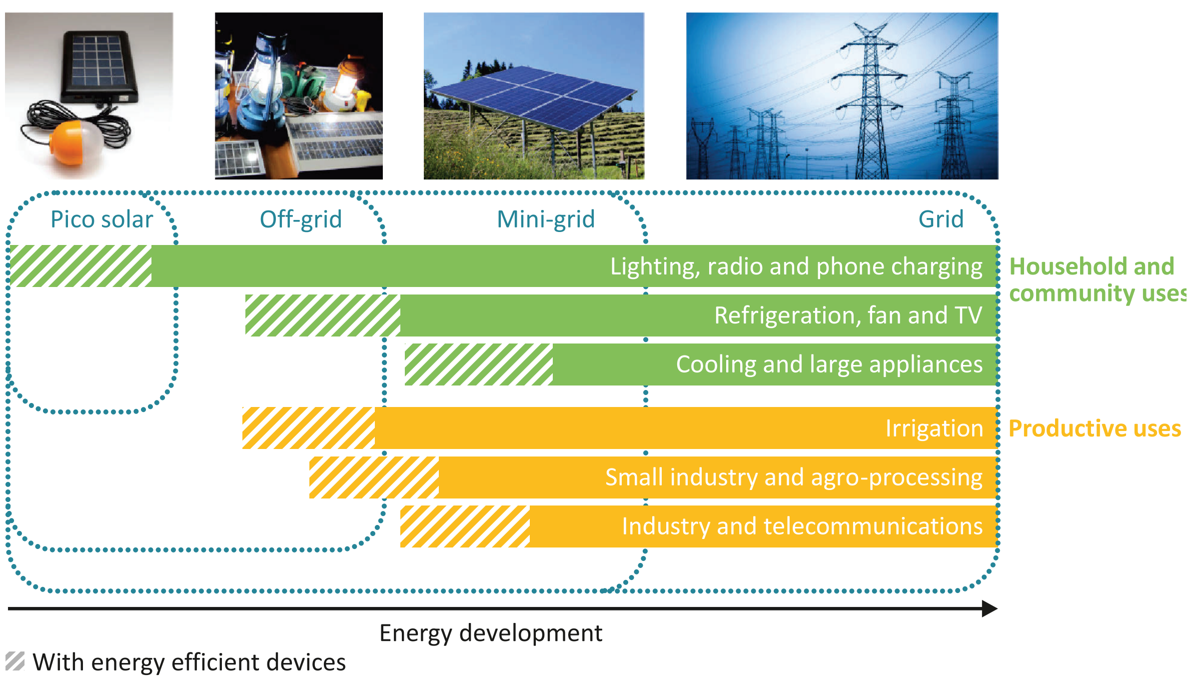
Recent developments with biomass-based generating systems have been encouraging. Unfortunately, with only a few exceptions (e.g., Khandker et al. 2014b), international organizations are not systematically collecting statistics on renewable energy use in rural areas of developing countries. The global status report on renewable energy is based mainly on supply statistics (REN21 2017), making it difficult to detail the progress of renewable energy for households and businesses in off-grid areas for all developing countries. With the implementation of the Multitier Framework supported by both the International Energy Agency (IEA) and the World Bank, this situation may change.

Efficient lighting can be provided by a variety of service providers, ranging from grid systems to pico (small) solar (figure 4-1). The heavier uses of electricity (e.g., cooling, irrigation, and small industries) generally must rely on large grid or mini-grid systems. In the past, the main providers of electricity operated large grids, but today many appliances with lower levels of electricity consumption can be powered by renewable energy.

The pathways between electricity adoption and such development outcomes as higher income, better health, and increased education are quite complex. This complexity helps to explain why many past studies have preferred to use such methods as consumer surplus to measure the benefits of electricity. Consumer surplus methods do not detail the impact pathways of electricity on development, but instead measure the value of higher levels of lighting service, as represented by people's willingness to pay for lighting service. However, to understand the benefits for society, it is necessary to analyze the ways in which electricity affects development outcomes.

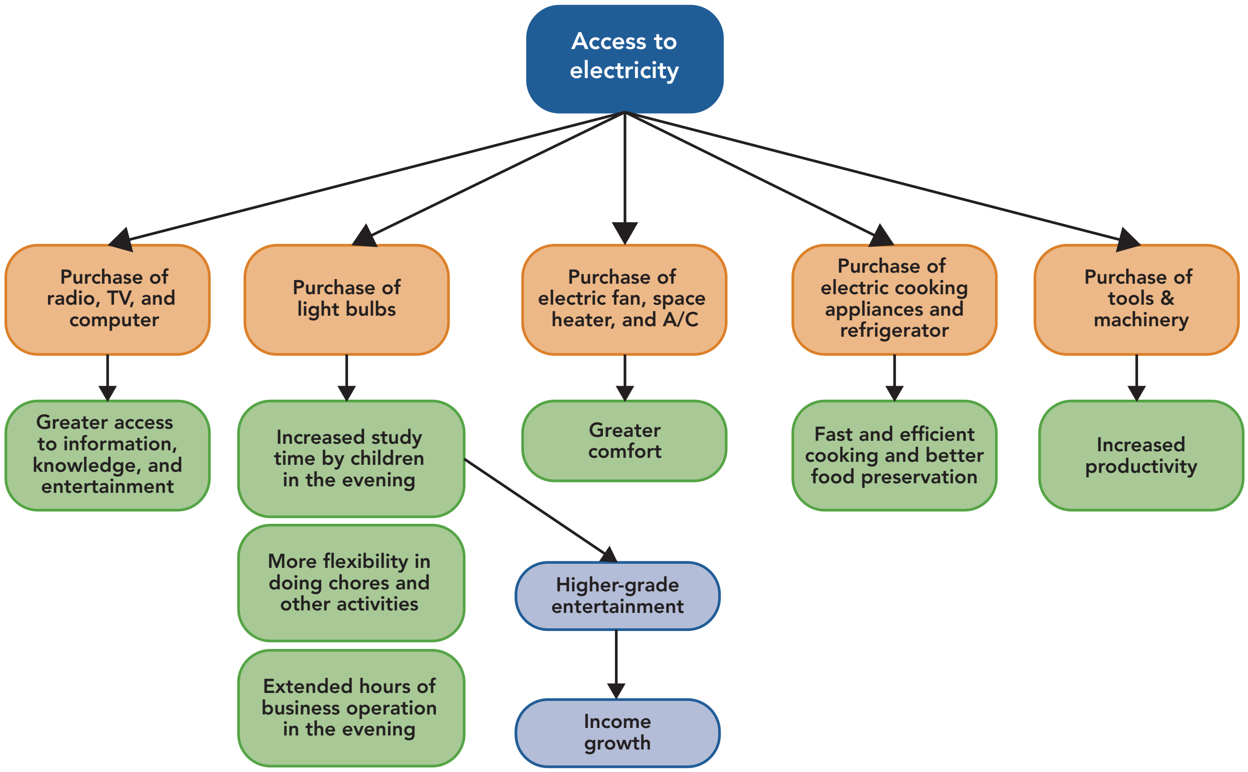
The pathways of electricity adoption for development all start with the purchase of appliances (figure 4-2). After adopting electricity, households begin to buy appliances, starting with electric lights, followed by radios, TVs, computers, electric fans, space heaters, air conditioning units, cooking appliances (e.g., microwave ovens and rice cookers), and refrigerators. All such household assets can be easily measured.

Figure 4-1. Matching of energy services with possible energy providers



Source: IEA 2017.

Figure 4-2. Benefit pathways for household electrification



Source: Barnes and Samad 2017.
Note: This figure was first used in World Bank (2002b), and was further developed in later studies.

Measuring the benefits of having adopted these appliances is somewhat more difficult, but is quite possible with appropriate survey questions (Barnes and Samad 2017). The appliances lead to immediate and long-term impacts for a host of outcomes (figure 4-2). For example, households enjoy far brighter lighting by using electric bulbs instead of kerosene lamps. Because of higher-quality lighting, it can be expected that household members will engage in a wider range of activities. For example, children might spend more time studying, while adults might engage in such productive activities as making handicrafts. With an increase in children's study hours, one can expect that they will have higher school attendance and eventually higher grade completion. This is not only a better outcome in its own right; it might also result in higher future income. For some households, income might also increase because home businesses can be kept open longer in the evening.

The types of energy used in households have significant consequences for the health of family members—particularly women—and the environment. Of course, the adoption of both electricity and appliances is related to household income. But before higher levels of energy access can occur, even well-off households have no choice but to use fuels and appliances with low levels of benefits. In most of the developing world, people rely on traditional ways of cooking and heating. Typically, biomass fuels (e.g., fuelwood, dung, or crop residues) are burned in traditional stoves that are highly inefficient and harmful to health. The time and effort spent collecting biomass fuels have been increasing throughout the developing world because of localized biomass fuel shortages. The primary group affected by this increasing drudgery is women. In most regions, women play a crucial role in biomass management and are largely responsible for collecting and using the fuels.

Modern cookstoves (e.g., improved biomass, electric, or LPG) are more efficient for cooking food than traditional ones. The result is that households can cook using less fuel (biomass in general and fuelwood in particular). Thus, the adoption of modern cooking methods saves fuel, which, in turn, frees up time or money. A family's savings in disposable income can be spent on the purchase of consumable and durable goods, entertainment, and income-generating activities. Using better stoves might save households time (e.g., fewer hours spent collecting fuelwood and faster cooking compared to a traditional stove). This time savings can be used for childcare, entertainment, income generation, and other productive activities. Another important benefit of improved cookstoves is better health for all household members, especially women. By using less biomass fuel and having complete fuel combustion, improved cookstoves emit less smoke and pollutants, thereby reducing the likelihood of health hazards linked to indoor air pollution (IAP).

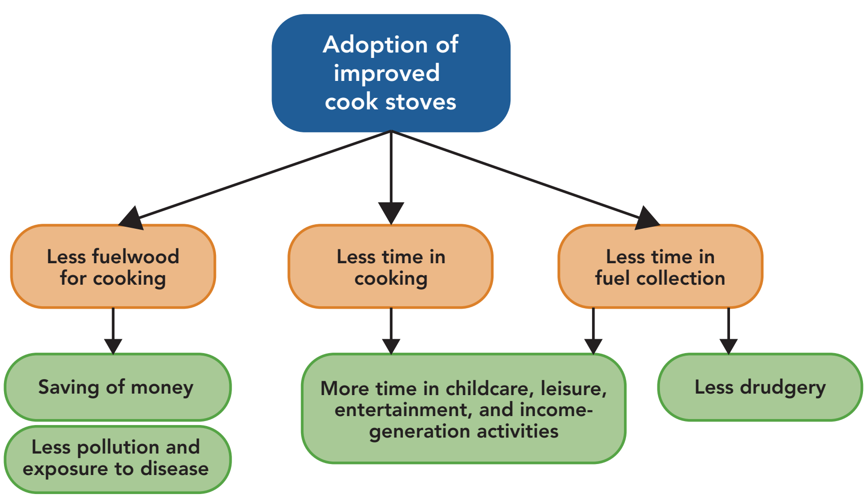
The benefits of using improved biomass stoves, electricity, and LPG for cooking are also related to household income (figure 4-3). Once access to these fuels becomes available, the first adopters are usually households with higher incomes. However, with appropriate government policies in place, the barriers to purchasing appliances and higher-value fuels can be lowered. As a result, even low-income households can, over time, take advantage of access to more modern forms of energy and appliances.

Measuring the benefits of energy access and clean cooking programs, compared to the costs of the interventions, is not easy. It requires sorting out the complicated pathways through which energy access and clean cooking affect development outcomes, along with conducting household and community surveys. Once these steps are completed, standard methods can be applied to disentangle and measure program benefits.

The Benefits of Modern Energy Access

There is a wide body of literature on the role of modern energy services in raising households' standard of living. This section reviews the literature on the wide-ranging benefits of adopting electricity and cleaner cooking methods.

Figure 4-3. Flow diagram showing direct benefits of household adoption of improved cookstoves



Source: Barnes and Samad 2017.

Electricity

Once households are connected to electricity service, the immediate benefit that household members enjoy is a higher quantity of improved lighting. The reason is that electric lighting is far superior to the traditional forms of lighting used prior to electrification. As previously mentioned, electric lamps, depending on the lighting technology, can emit 100 times more light than kerosene lamps or candles (O'Sullivan and Barnes 2006; Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1998). A study in Rwanda indicates that adopting electricity increases the number of lighting hours per day (Bensch, Kluve, and Peters 2011). This finding is corroborated by surveys conducted in Bangladesh (Barkat et al. 2002) and the Philippines (World Bank 2002b).

Many studies have documented the positive benefits of better lighting. For example, a study in a remote location of Nicaragua found that solar home electricity resulted in more family gatherings in the evening and higher levels of school attendance (box 4-1). These study

Box 4-1. Lighting a Pathway to Development in a Remote Corner of Nicaragua

Waspam, one of eight municipalities in Nicaragua's North Caribbean Coast Autonomous Region (RACCN), is situated along the upper reaches of the Rio Coco—Central America's longest river—separating Nicaragua from its northern neighbor, Honduras. Home to indigenous Miskito Indian tribes, Waspam has a population of 47,231 (2005 figure), scattered in undeveloped, remote villages. Until 2003, the area had been sidelined by the development process, lacking electricity and running water. Ocote pinewood provided villagers their main source of lighting. Without electricity distribution lines or potential dates for installing power plants, grid extension was not feasible, leaving Waspam's communities without access to a reliable food supply, quality health care and education services, and communication with the outside world.

Planners from Nicaragua's National Energy Commission (CNE) developed a unique project to provide Waspam's communities better lighting and other benefits from solar electricity. Launched in 2003, with US$1.04 million in Inter-American Development Bank (IDB) financing, the Solar Electrification Project established a consortium of development partners for electricity supply (Isofoton), installation (Tecnosol), and bill collection and equipment maintenance (Pana-Pana). Of the total project cost, 85 percent (US$884,712) was subsidized, while the other 15 percent (US$156,125) was recovered over a 15-year period through a user tariff.

Following installation, a 17-person team was contracted by the consortium to administer the project, with a local office established for conducting meetings to improve service quality. Preventive maintenance is conducted every six months, repairs are made when parts break down, and a monthly bill collection system is being implemented. A radio program created by the consortium, called "Light and Energy," aims to incentivize customers in the care and maintenance of their solar PV systems and disseminate information on the terms of their contract in order to promote a culture of payment.

The advent of electricity is transforming the lives of Waspam's communities. With electric lighting, households have reduced the amount of money previously spent on radio and flashlight batteries. Neighbors can visit each other in the evenings without fear of running out of ocote pinewood, children can do their homework in the evenings instead of waiting until dawn, adults can attend continuing education classes in the evenings, and there is more communication between parents and children. Children's school attendance is higher, and babies are being born in well-lit clinics. With electricity, villagers are optimistic that better food, running water, medicines, and better schools will follow.

Sources: El Nuevo Diario 2004; Isofotón n.d.; Isofotón, Tecnosol, and Pana-Pana n.d.; Martínez 2004.

findings are consistent with those of other developing countries (Khandker et al. 2014b; Khandker, Barnes, and Samad 2012; Barnes, Peskin, and Fitzgerald 2003; Nieuwenhout, Van de Rijt, and Wiggelinkhuizen 1998; van der Plas and de Graaff 1988; Filmer and Pritchett 1998). In rural Bangladesh, household adoption of electricity increased study time by 22 minutes per day for boys and 12 minutes per day for girls (Khandker, Barnes, and Samad 2012). In rural India, the corresponding increases for boys and girls were 12 minutes and 14 minutes per day, respectively (Khandker et al. 2014a). In Bhutan, having electricity increased study time by 10 minutes per day for all children (Kumar and Rauniyar 2011).

Increased study hours because of electricity have also been found to improve educational attainments (Kulkarni and Barnes 2004; Saunders et al. 1975; Madigan, Herrin, and Mulcahy 1976; Barnes 1988; Khandker 1996; World Bank 2002b; Tanguy 2012; Roddis 2000). In Bhutan, electricity led to an increase in grade attainment by up to 0.74 grades (Kumar and Rauniyar 2011). A macro-study of Brazilian counties covering the period 1960–2000 found that an increase in electricity was associated with a 22 percent reduction in illiteracy (Lipscomb, Mobarak, and Barham 2013). 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 the school enrollment of boys by up to 8.2 percentage points and of girls by up to 9.5 percentage points (Khandker, Barnes, and Samad 2013). The same study found that electrification increased boys' and girls' grade attainment by up to 0.16 grades and 0.08 grades, respectively. A study in India found that boys' and girls' school enrollment went up by 6 percent and 7.4 percent, respectively, as a result of electricity (Khandker et al. 2014a). In rural Bangladesh, electricity increased the respective grade attainment of boys and girls by 0.23 and 0.16 grades. A study in Colombia indicated that the education of heads of households was higher for families with electricity, even after controlling for level of family income (Velez, Becerra, and Carrasquilla 1983).

The relationship between adopting electricity and increasing income or expenditures has been the topic of a large body of research (Cabraal, Barnes, and Agarwal 2005; World Bank 2002a, 2002b). In India, for example, a national cross-sectional study of rural areas found that grid electrification led to a 39 percent increase in incomes (Khandker et al. 2014a), while in Bangladesh, a cross-sectional study using a national rural energy survey found a 21 percent rise in incomes resulting from grid electrification (Khandker, Barnes, and Samad 2012). Respective studies in Bhutan and Nicaragua showed that electrification resulted in a 60–70 percent increase in nonfarm income (Kumar and Rauniyar 2011) and a 23 percent rise in women's employment (Grogan and Sadanand 2012).

A longitudinal study in Vietnam found that rural electrification had an impact on household income (Khandker, Barnes, and Samad 2013). For households with electricity, income growth was an average of 20 percent higher than that of households that did not adopt electricity. A study in Brazil found broad increases in labor productivity among households that might not have been able to adopt electricity had the power company based their planning strictly on costs (Lipscomb, Mobarak, and Barham 2013). Female employment also appears to increase after a community gains access to electricity. A study in South Africa on the effect of an electrification rollout campaign in 1996–2001 found that female employment increased by up to 9.5 percent specifically because of electricity adoption (Dinkelman 2011). This study found that household electrification saved labor in home production, which, in turn, allowed women to engage in market labor.

In addition to growth in household income, aggregate community-level productivity has also been found to increase as a result of electrification. 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). In India, where irrigation plays a key role in agriculture, this study found significant increases in farm production.[9] In Indonesia,

9. Beginning in the 1960s, the Indian government had a program for promoting electric pump sets. A later study in rural India again found that, due to electric pump sets, the productivity of small-scale farmers increased by about 50 percent (Monari and Mostefai 2001). For medium- and large-scale farmers, the increase was significant, though smaller, at 15 percent.

most productivity increases did not come from agriculture; rather, they resulted from new business activity (Barnes 2014). A study in Kenya found that income from some small-scale businesses doubled after introduction of a decentralized community electricity system (Kirubi et al. 2009). Similar to the Indonesia case (Barnes 2014), a study in the Philippines found that the availability of electricity did not lead to increases in irrigation and gains in agricultural productivity; however, it did lead to greater small-business production (World Bank 2002b). Finally, a study in Bangladesh found that the impact of electricity was much lower in areas using gravity-fed irrigation, compared to those with individual, agricultural pump sets (Asaduzzaman, Barnes, and Khandker 2009).

Later studies have confirmed the findings of earlier ones on the relationship between electricity and productive activities. A macro study in rural India during 1965–84 found a relationship between electricity expansion and manufacturing output (Rud 2012). For every one standard deviation in electricity connections, manufacturing output improved by 14.7 percent. But not all studies have found such a relationship. For example, a study in Benin found that, while the adoption of electricity encouraged people to undertake new production activities, there was no evidence of significantly higher profitability among firms (Peters, Vance, and Harsdorff (2011). It should be cautioned, however, that such studies often examine short-term profits, during which period the capital costs of new machinery can be quite significant.

In Peru, the consumer surplus technique was used to calculate the benefits of watching TV, using data from the National Survey of Rural Household Energy (box 4-2). The survey was jointly conducted by the Ministry of Energy and Mines and the World Bank in 2005; the Ministry provided financing for the survey fieldwork, while the World Bank's Energy Sector Management Assistance Program (ESMAP) funded the survey design and preparation of the final report (Meier et al. 2010).

The health benefits of electricity can also be substantial. By switching from kerosene-based lighting to electric lighting, household members are less exposed to IAP. Kerosene-based lamps emit harmful pollutants (e.g., $PM_{2.5}$ and CO), which increase the risk of respiratory and cardiovascular diseases and mortality (Krewski et al. 2005; Samet and Krewski 2007; Tsai et al. 2012; Lam et al. 2012). Electrification makes it possible for households to acquire refrigerators, which allow for better food preservation and improved quality of life. In households with refrigerators, household members might have fewer incidences of food spoilage and stomach ailments. Because food can be preserved for longer periods of time, fewer trips to purchase groceries are needed. A study in Argentina found that increased electricity coverage led to greater acquisition of refrigerators (Gonzalez-Eiras and Rossi 2007).

Modern Cooking

A wide body of literature has shown the hazards of cooking with solid fuels using traditional biomass stoves. The IAP resulting from the incomplete combustion of biomass fuels has been identified as a leading risk factor for the global burden of disease (WHO 2016). Each year, IAP accounts for an estimated 3.8 million premature deaths, making it the second leading cause of disease behind smoking (Smith et al. 2014).

Numerous studies have shown the benefits of clean cooking over traditional methods. One study found that replacing traditional stoves in Ghana with the Gyapa improved stove reduced fine particulates in the kitchen by 52 percentage points (Pennise et al. 2009). That study also found that introducing an ethanol stove in Ethiopia reduced $PM_{2.5}$ concentrations in the kitchen by 84 percentage points. A study in Guatemalan villages in 1993–94 found that concentrations of CO and $PM_{2.5}$ were higher for open-fire cooking (22.9 ppm and 5.31 mg per m^3, respectively) than for gas stoves (3.5 ppm and 0.13 mg per m^3, respectively) (Naeher et al. 2000). A recent study in rural Madagascar comparing traditional and improved biomass cookstoves found that the improved stoves reduced CO concentrations in the kitchen by 69 percentage points (Dasgupta, Martin, and Samad 2015).

Box 4-2. Estimating Benefits of Television Viewing in Peru Using Consumer Surplus

The estimation of consumer surplus of television viewing in Peru was possible because consumers in areas without grid electricity use car batteries to watch television. These car batteries were charged in nearby town where electricity was available from the national grid system. The use of batteries for watching television is more expensive that plugging directly into a grid system, so it was possible to construct a simple demand curve of television viewing according to the price and quantity of television viewing for battery and grid powered televisions.

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

The table below shows the viewing hours and costs for the three main types of TVs: B&W powered by car batteries, plug-in B&W, and plug-in color. The cost reductions from switching from car battery–powered B&W TVs to plug-in B&W and plug-in color TVs are 0.131 (= 0.16-0.0288) soles per viewing hour and 0.115 (= 0.16-0.0450) soles per viewing hour, respectively.

Viewing hours and costs for three TV types

	Car battery, B&W	Grid, plug-in B&W	Grid, plug-in color
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. The net benefit of switching from plug-in B&W TVs to plug-in color TVs (consumer surplus) is estimated at 13.9 soles per month.

Source: Meier et al. 2010.
Note: Exchange rate: 3.2 soles equal 1 US dollar.

About 730 million tons of biomass are burned every year in developing countries (WHO 2006). Though cooking fuels are seldom addressed in the climate change debate, there is evidence that biomass fuels burned in traditional ways contribute to a buildup of greenhouse gases (GHGs) (Venkataraman et al. 2010), as well as other climate-risk factors, including black carbon in the atmosphere (Ramanathan and Carmichael 2008). 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 used for energy is estimated at about 2–2.5 billion tons (Yevich and Logan 2003; Fernandes et al. 2007). In addition, other products of incomplete combustion have large GHG impacts.

Studies on the benefits of electricity for lighting, productive uses, and higher education levels identify pathways between the use of modern energy and development. However, the links need to go one step further and provide the monetary benefits for communities and households so they can be compared with the costs of providing modern energy services. Common techniques for estimating the monetary benefits of modern energy services are examined in the next section.

Methods for Measuring the Benefits of Energy Access

Measuring the benefits of energy access for development has evolved over the years to include two basic approaches: (i) consumer surplus and (ii) regression-based techniques. Consumer surplus, based on the concept of willingness to pay, is perhaps the most common approach used in project appraisals. It is a solid economic technique that is not overly complicated to apply. Unfortunately, because of its simplicity, it has sometimes been misapplied. The main problem has been not quantifying energy demand based on consumer surveys. A second issue is that it measures many embedded benefits that may not be obvious even to seasoned researchers; for example, the consumer surplus from better quality lighting may measure such benefits as improved children's education and the parent's expectation that children will have higher incomes through better education. A third drawback is that it does not aim to measure spillover that can be key to evaluating a policy benefit of electricity access. In this context, regression-based techniques try to take the spillover into account; however, this method has its own set of problems.

The regression-based or direct approach, which is also based on consumer surveys, is more demanding. It uses multivariate estimation techniques to deal with confounding influences related to development outcomes. Also, since income and adoption of modern energy are often intertwined, it must deal with causality issues. Both approaches, discussed in the following subsections, are important for the LAC region.[10]

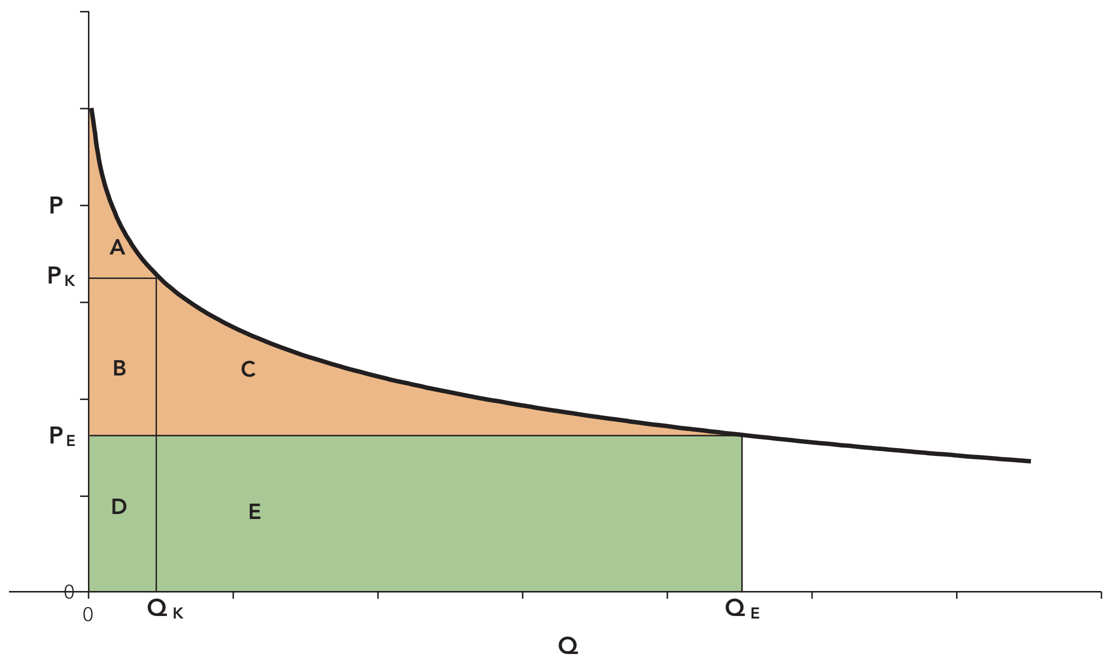
Consumer Surplus

The consumer surplus approach, which has long been used to measure project benefits, has been defined as the difference between the amount consumers are willing to pay for a product or service and the amount they actually pay for it. It is the monetization of benefits captured by consumers above what they must pay for a product or service. Willingness to pay accounts for *all* benefits that will be enjoyed from the product or service in question. Consumer surplus includes the benefits that consumers perceive they will receive based on their willingness to pay for a new energy service. If they do not have to pay all of what they are willing to pay—since modern energy services are cheaper than traditional alternatives—the difference is the consumer's surplus.

Two techniques can be used for deriving consumer surplus: (i) contingent valuation and (ii) use of a demand curve.[11] For contingent valuation, survey respondents are presented with two scenarios: one with modern energy services and the other without it. They are asked how much more they would pay for the scenario with modern energy services and this is their willingness to pay. The demand curve technique requires a consumer survey that measures consumer demand for energy services based on specific technologies. This type of analysis generally involves observing differing consumption patterns when consumers switch from a higher-priced to a lower-cost

10. Past project appraisals for LAC have been using an older version of the consumer surplus approach, and the regression-based method of analyzing the impact of electricity for development has seldom been applied.
11. The consumer surplus approach can be applied to a variety of energy services made possible by access to rural electrification (e.g., lighting, communication, entertainment, refrigeration, and space conditioning). This subsection focuses on the benefits of improved lighting service.

Figure 4-4. Estimating consumer surplus from household demand curve for lighting



Source: World Bank 2008.

technology. 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 higher-priced lighting (e.g., kerosene lanterns) to lower-cost lighting (e.g., one or more electric lamps).

This technique, using consumption and price per kilowatt-hour in defining consumer surplus, was first introduced by Anderson (1975) to evaluate the impact of rural electrification on development. It was further elaborated by a comprehensive study of rural electrification in the Philippines (World Bank 2002b). Because of the large benefits attributed to rural electrification, the technique was further reviewed by the World Bank (World Bank 2008). That study confirmed that that the consumer surplus method is valid for evaluating the benefits of rural electrification; however, it recommended defining the demand curve in a slightly different way.

With the adoption of electricity, households switch from kerosene to electricity for lighting. Because kerosene used in traditional lamps is a very 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.[12]

To measure the value of consumer surplus gained by switching to electric lights, it is necessary to have a demand curve for lighting, which allows for a measure of household benefit for each level of lighting consumption measured in kilolumen-hours. In figure 4-4, P_K and Q_K represent the respective price and quantity of kerosene

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

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 by switching from kerosene to electricity-based lighting is based on the following equation:

$$CS_E - CS_K = \text{area } (B + C) = (P_K - P_E)\, Q_K + \text{area } C, \qquad (4.1)$$

where the amount the household pays for kerosene (AP_K) equals area ($B + D$) or $P_K Q_K$; the amount the household pays for electricity (AP_E) equals area ($D + E$) or $P_E Q_E$; the amount the household is willing to pay for kerosene (WTP_K) equals the area under the demand curve between *0* and Q_K or area ($A + B + D$); the amount the household is willing to pay for electricity (WTP_E) equals the area under the demand curve between *0* and Q_E or area ($A + B + D + E + C$); the consumer surplus for kerosene consumption (CS_K) equals $WTP_K - AP_K$ or area A; and the consumer surplus for electricity consumption (CS_E) equals $WTP_E - AP_E$ or area ($A + B + C$).

The use of a properly-designed survey is necessary to measure the price of kerosene per kilolumen-hour (P_K), the amount of kilolumen-hours from kerosene (Q_K), and the price and kilolumen-hours from using electricity (P_E and Q_E). The first term in consumer 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. In figure 4-4, a constant elasticity demand curve (log linear) is assumed, as suggested by the World Bank (2008). However, it should be emphasized that, if additional points along the demand curve are available, they may be used to more accurately estimate it shape.

Recently, the LAC region has applied the consumer surplus method using lighting rather than kilowatt-hours to define the benefits of electricity in order to more accurately assess project impacts on development outcomes. Because of the more accurate measurement of benefits, projects previously considered economically unviable could be financed by the Inter-American Development Bank (IDB) (box 4-3).

Regression-Based Techniques

Using the consumer surplus approach to assess the difficult-to-measure benefits of modern energy services is considered a short-cut for using 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. This approach generally addresses whether the development of modern energy services is a cause or an effect of development outcomes. That is, appropriate 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.

The measurement of the impact of modern energy services for any change in development outcome must deal with whether the intervention is the cause of the effect. It is necessary to assess the counterfactual situation, defined as an outcome that would only occur as a result of some type of interventions. To illustrate, one can consider two identical households without electricity. For whatever reason, one household is provided with electric 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 comparison group (i.e., a control group). The goal is to come up with a participant group and a nonparticipant group that are identical in all aspects except their participation status in a project or program. The differences in the outcomes between the two groups can then be attributed to participation alone. Basically, identification strategies attempt to find the control groups in a way that satisfies at least three assumptions (Gertler et al. 2011):

Box 4-3. Justifying Off-Grid Projects in Ecuador Using Demand Lighting Instead of Kilowatt-Hours

Evaluating the economic sustainability of projects requires an improved approach to measuring benefits. Once consumers have been provided with low-cost electricity, it is often necessary to more accurately measure the benefits of electricity in order to justify projects. Previously, it may have been enough to simply measure the main benefits of providing electricity for easy-to-reach populations.

In the case of Ecuador, its electrification rates are among the highest in Latin America and the Caribbean (LAC). The International Energy Agency (IEA) reported in 2015 that the country's overall electrification rate had reached 97 percent by 2013, including virtually all urban residents and 94 percent of the rural population. Most investments in rural electrification have been based on national grid expansion, while investments in off-grid projects have been quite limited until recently. At present, the government has reached the "last mile" of its ability to provide grid-based electrification, meaning that small indigenous communities living in the Ecuadorian Amazon Basin and northern coastal lowlands will likely require off-grid solutions, which have high costs per kilowatt-hour.

Ecuador has long justified the investment of public resources in electrification based on a consumer surplus model that measures economic benefit based on the unit price for each kilowatt-hour of electricity. Using this method, the minimum required economic returns for last-mile projects could not be achieved due to their high costs.

A better economic method for measuring household benefits is based on the services provided by electricity rather than the price of each kilowatt-hour consumed (Barnes and Samad 2017). Household benefits can be linked to electricity services that people use, such as household lighting (demand of kilolumen-hours), television (watching hours), and radio (listening hours). Applying this improved method, seven mini-grids in Ecuador, previously considered economically unjustifiable, were approved.

Sources: IEA 2015a; Feron, Heinrichs, and Cordero 2016a; Javier Castillo A., Inter-American Development Bank.

1. The participants and nonparticipants are identical before the intervention occurs.
2. They are expected to behave in the same way after receiving the intervention (even though only the participant group receives the intervention).
3. During the intervention period, the participant and nonparticipant groups are not exposed differentially to other factors that could influence the outcome of interest.

Thus, at the heart of impact evaluation 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 very much by the nature of the intervention. Two types of biases can creep into finding valid comparison groups. They include program placement and self-selection bias.

Outcomes can be in monetary terms (e.g., income) or other forms (e.g., 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).

Despite these possible benefits, it is better to focus on the pathways through which modern energy services impact development outcomes (figures 4-2 and 4-3). These include the impact of substituting electricity for kerosene and such economic outcomes as income, expenditure, poverty, and employment. For the development outcome of education, methods are available on how to measure the impact of study time, school enrollment, and grade attainment.

Which Approach Is Preferred?

Measuring the benefits of energy access is not an easy task. Many earlier studies on electrification involved simple comparisons of households with and without electricity. The drawback of such approaches was not accounting for related factors. Today those earlier methods have evolved to include both consumer surplus and regression techniques for valuing the benefits of energy access. By necessity, the methods have become more technical and the surveys more complex. The result has been a greater understanding of how energy access impacts development outcomes, and, in turn, the significant monetary benefits of energy access.

A main finding of energy access research is that complementary conditions are necessary for programs to have significant impacts on development. Energy programs work better alongside education, water and sanitation, roads, and other infrastructure investments. Without good schools, household lighting is of little use in increasing children's study hours. 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 sum, the promotion of energy access needs to take into consideration the need for complementary investments.

This subsection discusses how and to what extent the monetary benefits of energy access can be combined to arrive at an overall assessment of the benefits of energy access. Many of the individual benefits of energy access, as measured by the methods covered in this report, cannot be added together. The reason is that adding benefits together might mean they are counted twice or even three times, leading to inflated results. 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 in the evening hours. Consumers want better-quality lighting for many varied reasons. The consumer surplus approach has been used successfully to capture the benefits of energy access. As previously mentioned, the advantage of this approach is that it includes all the benefits of a purchased product or service. In expressing his or her willingness to pay, the consumer provides an assessment of various types of services in monetary terms. By contrast, regression techniques attempt to measure the benefits in terms of direct changes in outcomes.

The question can then 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 to tease out the specific impacts of energy access for development outcomes. The regression approach has been the choice of impact evaluation specialists because of its flexibility in addressing 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 other contexts?

The precision of the regression approach to impact evaluation research is tempered by the difficulty of carrying out such studies. Causality issues are always difficult to resolve. Statistical techniques are quite complicated, 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 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 specific appliances actually being used. The use is discovered through household surveys especially designed to measure the monetary aspects of appliance use. Thus, the demand for lighting comes from electric lamps, kerosene lamps, or candles. The diffuse development outcomes (e.g., education, reading, and productive activities) are measured through valuation by the consumer of having better lighting in the household. Similarly, the demand curve for entertainment hours can be measured by the cost and use of battery or plug-in radios. In short, consumer surplus techniques for measuring demand for energy services are much simpler, and, with appropriate survey questions, are quite valid for evaluating project benefits. However, such factors as income and education do play a role in shaping consumer demand, so they should not be ignored. The greater simplicity of the consumer surplus approach is balanced by the greater need for a comprehensive household survey.

The strengths and the weakness 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 4-2). The approaches differ markedly, with each requiring careful application owing to differences in strengths and weaknesses. Generally, the regression approach, which has been mainly used 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. That said, there are exceptions to every generalization.

A final issue is whether the benefits of energy access assessed using the consumer surplus and regression approaches can be added together? The practical answer is generally no. These two approaches are alternate ways of measuring the same benefits. Under ideal circumstances, one method can be used to check 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 the desire of the consumer (e.g., to produce more handicrafts or open a small retail store in one room of the home). The regression approach can be used to directly measure the income from the impact of electricity on the activity (e.g., increasing handicrafts production or store sales). Therefore, in most cases, the benefits estimated using the consumer surplus and regression approaches should be left separate.

Methods for Evaluating Clean Cooking

Several fairly direct methods are available for assessing the non-health benefits of clean cooking. Cleaner fuels or improved biomass stoves can result in less time spent collecting fuels and cooking. This can be measured with an assessment of the value of time saved after adopting stoves or fuels that provide households with a cleaner environment. Studies have also found that electricity adoption,

Table 4-2. 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.

like the adoption of LPG or other cleaner cooking methods, impacts the time spent preparing meals. Thus, studies on the benefits of clean cooking need to assess the role of electricity. Another benefit of clean cooking is avoided time spent collecting fuelwood, which can be measured by comparing households that do and do not employ clean cooking methods.

Devising methods to measure the monetary benefits of clean cooking is complicated by the health issues linked to the inhalation of cooking smoke. For improved cooking methods, health outcomes (e.g., incidence of short-term illnesses linked to IAP, days lost due to illnesses, and cost of treatment) may be important. Other measures might include time spent related to cooking (e.g., collecting fuel and cooking). Finally, the expense of wood and other modern energy sources can have an impact on evaluating development outcomes.

The health outcomes of clean cooking can measure the values of the avoided days lost due to illnesses and avoided treatment costs. As indicated, evaluating health issues is a complicated research task and is best left to surveys conducted by dedicated health professionals. The number of questions and the intricate analysis goes beyond the scope of most energy surveys. As an example, a study in Mexico measured the reduction in IAP by comparing similar households with and without improved biomass stoves; however, the health benefits of the reduction were not part of the study (box 4-4).

Box 4-4. Pairing Kitchens in an Improved Stove Intervention Study in Mexico

Researchers attempting to measure stove pollution as part of a study on improved stoves in Michoacá, Mexico, faced the challenge that the Patsari stove developed for cooking Mexican-style regional food was located in many types of kitchen arrangements (e.g., open areas and relatively closed environments). The solution was to use a matched-pairs sample selection technique. A household screening survey was used to restrict kitchens to the region's more common arrangements. The selected configuration was a room enclosed by four walls that was not shared between families, use of wood for cooking, families with 5–9 members, and participating women's stated desire to use the Patsari stove after the project intervention. Most of the kitchens had wooden walls and laminated roofs, and about half had electric lighting.

In the paired-stove comparisons, the respective overall reductions in observed $PM_{2.5}$ and CO pollution as a result of installing the Patsari improved stove were 66 percent ($p < 0.001$) and 67 percent ($p < 0.001$). Perhaps more important, the Patsari stove reduced kitchen smoke concentrations across the distribution of homes to more predictable levels. Reductions in cooking smoke and particulate levels were especially noticeable in homes that previously used open-fire stoves for cooking.

Source: Masera et al. 2007.

Unfortunately, most of the health literature on clean cooking does not consider the social and economic benefits of shifting from traditional to more modern cooking methods. Some studies measure the time spent collecting fuels, but the saved time is rarely converted into monetary benefits. Also, health professionals are more interested in the reduction of disease or disability-adjusted life years (DALYs). This is done at a more theoretical level, applying the results of non-energy related health studies to populations that use or do not use clean cooking methods. To derive the monetary benefits of reductions in IAP, the reductions must be linked to improved health and how this impacts daily life. Health practitioners typically do not analyze in any great detail such aspects as time saved in cooking or changes in time use.

Among many populations, reduction in hours of food preparation due to clean cooking may actually have a higher annual monetary value than the reduction in diseases caused by IAP. Measuring the health benefits is complicated by the fact that the consequences of daily smoke inhalation may only be suffered in future years. The negative impacts of cooking with traditional stoves among healthy adults may manifest once or twice a year. By contrast, collecting fuelwood is commonly a daily or weekly task; thus, any reductions can add up to significant monetary values over the course of a year. Such complicated issues could be resolved using a more systematic monetary approach to researching the link between adoption of clean cooking practices with reduction in drudgery and improvements in health.

Conclusion

Today many development agencies are requiring better monitoring and evaluation. Many past investments plunged ahead into often unsuitable areas, with the resulting impacts of energy access limited to a small number of wealthy households. The techniques for analyzing the benefits of energy access in both monetary and more general terms can be helpful for directing programs toward areas in which improvements in energy access have the greatest impact on development. In addition, energy access programs can be coordinated with other development projects to ensure that the right complementary conditions are in place to make the most of modern energy. When this is done, the monetary value of the benefits is, in most cases, many times higher than the investment costs. This means that, when measured properly, the benefits of modern energy access in most situations are worth the investment costs. However, it is important to measure the impact of such energy investments in order to understand which types have the greatest impact for those still without energy access in LAC. The next chapter reviews some of the most recent effective efforts in providing improved sustainable energy access for poor populations.

Chapter 5
Improving Sustainable Energy Access

In recent years, a large number of manufacturers, distributors, and suppliers have created new ways of meeting the requirements for modern and sustainable energy services. This means that new types of equipment have become available for rural areas. This business line represents a new way of extending electricity service, traditionally provided by conventional distribution networks. This is not so say that grid expansion will not play an important future role in providing more people with electricity. However, the new equipment may be used for the vast numbers of people living in remote areas who are unlikely to have access to grid electricity in the foreseeable future.

In the LAC region, most of the remaining populations without electricity live in remote areas. These so-called "last mile" concentrations of people, located far from urban centers, are difficult to reach with conventional electricity grids. Each country in LAC, with the exception of Haiti, needs to develop ways to overcome the barriers to reaching these last mile customers. In the case of Haiti, grid distribution is likely the most cost-effective solution, given that country's dense population and low levels of electricity access. Before turning to specific models for reaching out to people with modern energy services, it is necessary to review lessons from past programs.

Ways of Providing Energy Services to Large and Small Communities

In LAC, three basic models have been developed to provide rural populations electricity service: (i) main grid extension, (ii) community networks, and (iii) individual home-based systems. As indicated, stepwise extension of the main grid can gradually advance electricity access in regions defined as priorities. Community networks can be developed using small generating systems based on micro-hydro, diesel, biogas, and other energy sources. Finally, individual home-based systems (e.g., solar home systems [SHSs], pico-hydro-, or small wind) can be used in isolated rural areas. This section provides an overview of appropriate government, business, and rural community association models for supplying electricity to remote rural communities. It covers lessons from past rural electrification programs and then turns to new approaches for reaching out to even the most remote populations.

Electricity Access through Distribution Grids

Grid-based distribution is the most common way to provide consumers electricity in both developed and developing nations. Electricity from grids can be extended to provide service to both households and community organizations, as well as for productive activities. However, since most new customers in the LAC region are located in poorer, remote areas, grid extension can become quite costly. Generally, the revenues to be realized from such customers cannot justify the expansion. Therefore, successful provision of grid-based service to poor and remote populations requires the availability of subsidies or low-cost government loans. In LAC, such resources are often from social investment funds, but they can also be allocated directly through national or regional budgets. For grid-based electricity systems, it is common for operation and maintenance costs to be borne by the distribution or power companies. Such costs are generally covered by tariff charges paid by electricity customers.

The costs of providing electricity to remote populations have taken several forms. Sometimes state power distribution companies simply incorporate the costs of providing electricity access into their cost of service. Regulators then must approve appropriate subsidies or tariffs so that these companies can recover their costs. For private enterprises, service concession contracts sometimes specify the amount of subsidies they can claim for connecting low-income customers. These agreements can be with federal, state, or local governments. Such funding might include the costs of grid expansion (e.g., design, equipment, materials, and construction labor) and connecting users to the grid (e.g., connections and gauge meters). The concessions sometimes (but not always) include internal house wiring. The additional costs of power companies can also be considered an investment cost that can be incorporated into the following tariff review.

Electricity companies can compensate for the costs of extending service to poor households in creative ways. For example, they might connect households located close to the distribution grids, avoiding the connection of remote households in the short term. Companies sometimes offer financing to cover the cost of connections and meters, which will be paid back as a charge on customer electricity bills. For electricity users connected to the grid without charge, flexible payment systems (e.g., pre-payment meters) can be combined with secured connections. All of these methods are generally applied within the context of a regulated electricity system.

Certain building blocks or principles are necessary for providing access to modern forms of energy to those without electricity service. These are not prescriptive solutions; in practice, many ways have been found to successfully develop programs for modern energy access. The lessons have been developed primarily for rural grid electrification, but they also apply to individual and community systems (Barnes 2007, 2011).

The first lesson is that most successful programs have a specialized institution that deals with and promotes rural electrification. This would be an organization or department with a high degree of operating autonomy for which the primary objective is the promotion of rural electrification. It is important that such an institution or department not be subject to excessive political constraints in the planning and promotion of electricity extension. Historically, a variety of institutional approaches have been effective. They include a separate rural electrification authority (e.g., Bangladesh), setting up rural electric cooperatives (e.g., Costa Rica), allocating rural electrification to a new department in the national distribution company (e.g., Thailand), and delegating it to a specialized office within the government and utility (e.g., Peru). The key is that, rather than relying on an existing energy ministry and power company—institutions with diverse responsibilities—the institution or department specializing in rural electrification would have a sole focus on devising plans and ways to promote the extension of electricity to new consumers.

The second lesson is that all grid rural electrification programs have subsidies for the capital costs of expansion. The use of public funds for rural electrification often leads to political interference at national and local levels. Politicians may regard public funding as giving them the right to interfere, but experience shows that this can be quite damaging. Once technical and financial decision making are undermined in the implementing agency because of political string pulling, so are organizational goals.

However, sometimes political pressure can be turned into a positive force as occurred in Thailand, where local politicians were encouraged to raise and contribute funds so that their constituents could receive electricity before the planned date.

Rural electrification is often a stepwise process that starts with the most promising areas with high population growth and then moves on to increasingly remote populations. All successful rural electrification programs have developed their own systems for ranking or prioritizing areas for rolling out electricity supply. Capital investment costs, level of local contributions, and density of consumers are among the factors usually taken into account. In Costa Rica, for example, the ranking of communities was based on their population density, level of commercial development, and potential electricity consumption.

Examples of subsidies for capital cost expansion can be found in Costa Rica and Tunisia (Foley 2017; Cecelski et al. 2007). Costa Rica's cooperative program started with low-interest loans, but also had other favorable circumstances for promoting rural electrification (box 5-1). In Tunisia, all capital expansion costs were covered by government grants. Having access to such low-cost financing and subsidies need have no ill effects on the implementing agency or the rural electrification program. But such loans and grants should never be provided to companies that are not covering their operating and maintenance costs through revenue collection. This will

Box 5-1. Success of Government and Cooperatives in Promoting Rural Electrification in Costa Rica

Costa Rica is one of rural electrification's unique success stories. By 1995, the country had succeeded in bringing a reliable and sustainable electricity supply to 93 percent of its total population, and today that figure has reach over 99 percent. In urban areas, coverage has reached 100 percent.

The key factors that enabled Costa Rica's rural electrification program to develop and flourish were not merely technical. A variety of social, political, and economic factors created a particularly favorable environment within which to launch the country's rural electrification efforts. Early and full coverage of urban areas provided a secure technical and financial foundation on which to extend the benefits of electrification to rural areas. By the mid-1960s, rural electrification had become an important social and developmental issue forcing its way onto the political agenda.

Costa Rica has a number of distribution models that appear to be working well. Its rural electric cooperatives have thrived and are acknowledged as providing a high level of customer service. Rural electrification has also been extended by ICE (Instituto Costarricense de Electricidad), a government-run electricity company. In addition, the country has municipal electricity companies serving some urban areas. The government has demonstrated a willingness to invest in rural development that is combined with the support of experienced and effective electricity supply utilities within the context of a strong egalitarian tradition.

Costa Rica is in the enviable position of being able to choose from among a number of well-working organizational models with which to complete and continue expanding its rural electrification service. While the conditions that led to Costa Rica's success may or may not be replicable elsewhere, valuable lessons from its experiences in success can be applied in many developing countries seeking to electrify their rural areas.

Source: Foley 2007.

only worsen their financial position, ultimately resulting in poor customer service.

A third lesson is that cost recovery is essential for the long-term effectiveness of rural electrification programs. When cost recovery is pursued, many other program elements can fall into place. Rural electrification prices set at realistic levels sometimes even lead to energy cost savings for new customers as they reduce their kerosene lighting costs. Charging the right price allows the electricity company to provide a supply in an effective, reliable, and sustainable manner to an increasing number of satisfied consumers.

Lowering financial barriers to obtaining electricity service is also important for encouraging adoption. Initial household-connection charges demanded by the power distribution companies are often a significant barrier to rural families' adoption of electricity (Barnes, Golumbeanu, and Diaw 2016; Golumbeanu and Barnes 2013). High initial connection charges are often a more significant barrier than monthly electricity bills. Reducing the initial connection charges or spreading them out over several years—even if it means charging more per kilowatt-hour—allows larger numbers of low-income rural families to obtain an electricity supply. In Bolivia, for example, a small local grid, despite charging 25–30 cents per kilowatt-hour, immediately doubled its number of consumers when it offered them the option of paying for the connection cost over five years.

Another lesson is that rural electrification programs benefit greatly from local community involvement or suffer because of its absence. The thinking in many utilities is often oblivious to the importance of local community involvement. Rural electrification is viewed simply as a technical matter of stringing lines to grateful consumers. However, successful programs have had many innovative ways of involving local communities. In Costa Rica, for example, consumer meetings were held before the arrival of the electricity supply, helping to avoid costly and time-consuming local disputes (Foley 2007). In Mexico, local development funds were used to provide part of the capital necessary for extending electricity to participating communities (Gutierrez-Poucel 2007).

Finally, many countries tend to stick with urban design standards and do not take advantage of opportunities for reducing the construction and operating costs of rural electrification. Where lighting and use of small appliances are the main expected uses of electricity, there is no reason to apply the design standards used for more intensive urban systems. In many cases, careful attention to system design enables the reduction of construction costs by up to 30 percent, contributing significantly to the growth of rural electrification coverage. Each country will have its own cost-saving opportunities for rural electrification planners. For example, Costa Rica adopted the well-proven, low-cost, single-phase distribution system that has been used in the United States rural electrification program since the 1930s. Some locations can benefit from single-wire earth return (SWER) systems, which can be even less expensive.

Community Service Providers in Off-Grid Systems

One possible way to provide service to remote populations with little or no grid electricity is through community networks or local cooperatives. Such enterprises might provide electricity service at the appropriate scale and quality to meet the basic needs of households and for productive activities. In such systems, the price of electricity is often quite high compared to rates for urban users owing to the lack of economies of scale. In such communities, one option for extending service to the poor is basing tariff systems on the payment ability of its members. Despite high tariff charges, electricity expenses might be reasonable compared to the cost of buying kerosene or purchasing and recharging batteries. For small communities, diesel systems are quite expensive, at US$0.40–$0.60 per kilowatt-hour. As a result, depending on the availability of local resources, some microenterprises are turning to renewable energy for electricity generation.

One early pilot program utilized extensive subsidies to provide electricity service to people living on Chile's Tac Island (box 5-2). The island's households, health center, and schools received reliable round-the-clock electricity supply. Families were able to use washing machines, dryers, and some electric tools due to their agreement to spread out electricity use during peak and non-peak hours. Nevertheless, the management of running the system ran into difficulties from the start. Due to technical difficulties, the system used more diesel than originally designed.

Community systems must have sound management. This might mean light-handed electricity regulation (Brown et al. 2006; Tenenbaum et al. 2014). Local electricity companies face complex decisions regarding monthly service charges, consumption metering, and service termination methods in case of late payment. The development of good relations between the electricity microenterprise and the community, along with a sense of fairness, generally goes a long way toward the success of such businesses. As in the case of the Chile project, such businesses may require subsidies for the development, construction, and installation of equipment in order to facilitate a profitable operation. Setting such subsidies is

Box 5-2. Early Lessons from Chile's Tac Island Wind-Diesel-Battery Hybrid Project

In the year 2000, a wind-diesel generation pilot project was developed to provide reliable electricity on one of Chile's islands. The project included two turbines, deep-cycle battery storage, a back-up diesel generator, electronic load management systems, a distribution network, transformers, and indoor installations. Under the pilot project, 80 families, a first aid station, and a school were supplied round-the-clock electricity using a hybrid wind-diesel-battery system.

Institutions and Financing

The Sociedad Austral de Electricidad, the region's electricity distribution company, subcontracted most system operation and maintenance to Wireless Energy. The responsibility was for a 10-year supply agreement, with the possibility of a 10-year renewal at the end of that period. Financing, in the amount of about US$120 million, was provided by the National Fund for Regional Development, the local electricity company, and the U.S. Department of Energy, as well as beneficiaries. Subsidies for consumers amounted to about 94 percent of total project costs. The reason for the high subsidies was that this was considered a first experimental project in providing renewable energy to Chile's island populations.

Key Lessons Learned

This pioneer pilot project has many replicable lessons for projects in similar remote areas. From the project's outset, a sustainable tariff and a robust service-provider contract were put in place. These two key elements protected the beneficiaries when the high cost of the hybrid-system maintenance contract obligated the service provider to temporarily switch to diesel-only generation. If the service-provider contract had not been strong, the business would have been disputed and the system would have been abandoned. More recently, the service provider has begun to return to the lower-cost, hybrid generation system, which originally displaced close to 50 percent of the required diesel. Tariff revenues were sufficient to cover operation and maintenance costs of the wind-diesel hybrid generation system.

The cost of this system was quite high and today other options would be considered for providing renewable energy access to remote island populations. However, the idea behind this pilot project was to see whether providing grid-quality electricity to populations on remote islands would be feasible.

Sources: de Carvalho 2002; IDB n.d.

one reason why light-handed regulation is necessary to oversee the development of local electricity businesses. Thus, many factors enter in to ensuring that small-capacity community systems can operate sustainably.

Decentralized Distribution of Energy System Equipment

The price decline for such existing technologies as PV systems and LEDs, as well as deep-cycle batteries, has led to new ways of serving households in areas without access to grid electricity. Furthermore, local manufacturers of improved stoves are increasing, along with global awareness of the health impacts of solid-fuel cooking using open fires or traditional stoves. With the exception of flashlights, the main source of electricity has historically come from national or local grid systems. Today new decentralized options are becoming available for providing electricity service. These include SHSs and other off-grid technologies, which are being developed and marketed to household consumers.

It has seldom been recognized that rural people have, for many years, used car or motorcycle batteries to provide basic household lighting and to power television. Nowadays, such new developments as thermo-electric devices can transform heat into small amounts of electricity when attached to household cooking stoves. Small household lighting systems are now available for task-specific work. Many of these technologies are becoming more mainstream, and a host of manufacturers are producing them.

Most equipment manufacturers and distributors of these new energy products focus on basic energy needs or services. One new development is the emergence of solar lamps with rechargeable batteries and solar kits that can provide direct current for recharging a variety of small appliances. Mobile phones, radios, lamps, and even televisions can be powered using a combination of solar energy and rechargeable batteries. Although these systems have higher prices per kilowatt-hour, they also have lower upfront costs for a lower level of electricity service.

Clean cookstoves also fall into the category of decentralized technologies for providing better access to modern energy services. New rules being developed for cookstoves define the standard performance of firewood stoves. The ISO International Workshop Agreement (IWA) has worked on performance indicators for improved biomass stoves (GACC 2016). These include thermal efficiency of the stove, along with emissions of fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO) into the kitchen area. The issue of emissions transmitted to the community, perhaps through a chimney, must also be addressed. Finally, stoves should be safe to use. International and local stove manufacturers are offering stoves of higher quality and greater efficiency than traditional stoves. These more sophisticated, improved models are often priced higher than traditional stoves, which are produced without quality control.

Creating Favorable Institutional and Policy Conditions for Providing Energy Services

The UNDP and the IDB have had a variety of experiences related to the importance of reducing risks to facilitate investment in renewable energy. This goes along with ways to eliminate certain political barriers; improve legislative, regulatory, institutional frameworks; and facilitate national-level investment in sustainable energy. The mechanisms to create favorable conditions for providing energy services can be grouped into (i) energy policy and (ii) funding to facilitate credit access.

Energy Policy Mechanisms

Energy policies must be favorable to making energy development sustainable and encouraging local participation in projects. Such policies need to include innovative regulations, such as those found in Chile, to facilitate providing energy equipment to households and communities. As an example, many countries have taxed imported solar panels, making it virtually impossible for households to afford them. Such a policy existed in Peru before the international loans for grid extension and household energy systems pointed out the problem that systems affordability could be greatly improved by eliminating the tariff (box 5-3). Thus, energy policy mechanisms enhance, rather than block, the promotion of decentralized options for rural electrification.

In addition, the provision of loans or subsidies might facilitate the development of small enterprises that provide electricity to remote populations. For example, Ecuador, with assistance from the IDB, has created a public service law to promote a wide variety of actors to carry out the promotion of electricity to remote populations (ANRE 2015). The Public Service's Organic Law of Electric Energy indicates that it is the responsibility of the state to provide electricity for rural development projects in areas not already served by the grid electricity system. The responsible institution is the Ministry of Electricity and Renewable Energy with support from the Ministry of Finance. The regulatory institution for electricity oversees rural energy projects, ensuring they are safe and follow established practices. Under the law, the distribution companies are responsible for identifying, implementing, operating, and maintaining the energy infrastructure for providing electricity to remote populations.

Funding Mechanisms to Facilitate Credit Access

Funding for providing modern energy to those without service is also a necessary component of any sustainable energy strategy. A UNDP-commissioned study on small-scale finance experiences in Burkina Faso, Kenya, Nepal, and Tanzania concluded that governments can play a catalytic role in financing and stimulating the development of energy alternatives for those without modern energy services (Morris and Kirubi 2009). The study indicated that governments must take the lead in planning and identifying opportunities for providing energy services to various regions. This means that governments should provide support to regional assessments and technical

Box 5-3. Peru Cross-Subsidies for Solar Home Systems

The provision of renewable energy services has been fully integrated into Peru's electricity access program, which provides households regulated service. Through its national regulatory body, OSINERGMIN (Organismo Supervisor de la Inversión en Energía y Minería), the Peruvian government set up a system of cross-subsidies by establishing a regulated tariff to support solar PV systems. The idea was that existing grid-based customers would finance the difference between the costs of solar home systems (SHSs) and grid electricity service. That is, all customers in a service company's territory, both on- and off-grid, would pay a similar price for electricity, meaning that remote rural households could enjoy the same low tariffs as grid-connected households. Nine distribution companies in 16 regions participated in co-financing the project. The distribution companies provide the SHSs and contract small- and medium-sized enterprises (SMEs) to collect monthly bills and provide SHS operation and maintenance. The SMEs are provided a portion of the cross-subsidies collected by the distribution companies earmarked for remote, renewable energy systems.

The justification for the subsidies was that everyone in Peru should be able to enjoy the benefits of electricity access. Since households with electricity had already been provided subsidies for the construction of the electricity grids, it would be fair to ask them to provide the financing for households that had not yet been able to take advantage of the benefits of electricity. The cross-subsidy would make SHSs more affordable. The project also focused on promoting productive uses of electricity for small businesses through NGOs. In addition, a market strategy was developed for electricity suppliers to provide distribution companies assistance in providing off-grid services to households using solar PV.

Source: World Bank 2011.

overviews of modern energy systems. This would include companies capable of providing energy services in priority areas.

Evaluating the potential for sustainable energy solutions should also include the cost of the service, potential for productive use, and capability of institutions to provide financing for the poor. Policies and public investment for rural energy should include a component to support expansion of small-scale finance. As happened in Peru, the government should provide a platform for information exchange and collaboration among sectors to facilitate the development of local providers of energy services (box 5-3). The goal is to identify specific issues that might be hampering providers from expanding small-scale financing. Key factors would include support for promoting awareness about how small-scale finances can make a difference in providing energy services and publicity on available loans for small-scale energy providers.

One way to formalize the role of financing involves the development of specialized energy funds. A variety of styles have been developed for energy funds in developing countries, which are the topic of the next section.

Role of Energy Funds for Access to Sustainable Energy Services

The level of necessary investments to achieve the 2030 target for expanded electricity access for all is quite high. Reaching the universal access goal will require developing innovative partnerships between public and private sectors. This is a delicate issue, given that large subsidies can adversely impact both markets and innovation, while minimal subsidies can mean that no private companies will enter the market to serve mostly poor, rural populations.

The development of models to ensure universal access to sustainable energy services requires support for businesses, microfinance organizations (MFIs), and nongovernmental organizations (NGOs) serving poor and remote populations. The World Bank, along with governments in developing countries, has been instrumental in developing models for supporting decentralized energy systems. Called by various names, these models include energy funds in Africa (Barnes 2014; AfDB 2016) and financing systems in Bangladesh (World Bank 2012). For Bangladesh, the financing model has worked quite well, with more than two million SHSs sold to rural households without grid electricity. Recently, the program has expanded into offering locally manufactured, clean cookstoves.

It is common for energy funds to be located in local development banks or specialized energy units (World Bank 2012), which have the ability to blend both loans and subsidies and provide them to qualified organizations. They are responsible for setting quality standards because they do not want to loan out money for systems that fail before the loan is collected. The NGOs are responsible for marketing and, in many cases, financing stoves and small-scale renewable technologies over a period of time (Barnes 2010b). Once qualified technologies become available under a lending window, technical assistance for developing awareness campaigns is also important. The manufacturers can then promote their stoves or renewable electricity technologies through both private retailers and partnerships with NGOs to reach people that cannot afford the upfront costs.

In Chile, this model was given a slightly different twist (box 5-4). The unit responsible for promoting SHSs was located in the National Electric Power Company, supported by the government's regional development funds and IDB financing. The project's capital costs were covered mostly by grant funds, with operation and maintenance paid through monthly household fees.

Based on program experiences, the UNDP has promoted a CleanStart model for financing sustainable energy services through companies that distribute equipment for energy systems (UNCDF and UNDP 2012). Most of the needed elements for promoting access to decentralized energy solutions are part of the CleanStart model (figure 5-1). These include the fuel, product development, equipment manufacturer, marketing, sales, consumer financing, and after-sales service. Close attention is paid to development of the energy provision system proposed by the UNDP's EnergyPlus Guidelines (UNDP 2015).

Box 5-4. Stand-Alone PV Systems: Promising Solution for Chile's Off-Grid Zones

Chile has made impressive progress over the past two decades in providing its population of nearly 18 million electricity access, mainly through extension of the national grid. By 1992, the urban electrification rate had already reached 97 percent. In rural areas, where about 10 percent of people live, more than 97 had electricity by 2013. Today, less than 1 percent of the total population—comprising mainly about 20,000 indigenous people living in rural areas—remains without electricity access. These people will likely require off-grid solutions using renewable energy. In Chile's remote, arid and semi-arid northern region of Coquimbo (Region IV), solar photovoltaic (PV) energy has a tremendous potential to service last mile customers (Feron, Heinrichs, and Cordero 2016b).

Bringing Light to Remote, Northern Provinces

In 2005, the Chilean government awarded the National Electric Power Company (CONAFE) a contract to implement a pilot off-grid project in Coquimbo's three provinces: Elqui, Limarí, and Choapa. Known as Installation of Stand-Alone Electricity Systems, the project supplies households and establishments in the provinces' 15 municipalities basic electricity service using individual, stand-alone PV systems. Financing for the pilot was provided by the National Fund for Regional Development (FNDR), the IDB Investment Credit Program, and a UNDP project. Before implementation, CONAFE created a new administrative division, Renewable Energy Solutions (SER), dedicated to working exclusively with non-conventional renewable energies in its Region IV Management Zone.

Ensuring Sustainability of Pilot Investment

The second phase of the project, which began in July 2007, focuses on operation and maintenance of the systems installed under the first phase. Households pay about US$2.50 each month for electricity service, which helps the regional government maintain the system over the 10-year implementation period. Users sign supply contracts and are provided training on how to use the systems, including cleaning panels, maintaining panel orientation toward the sun, and ensuring equipment is not abused. The clients own all indoor system components, while the regional government owns the PV systems. Throughout implementation, CONAFE has maintained continuous contact with the user communities and government authorities. The pilot's success offers useful lessons in institutional, economic, and social sustainability that can be replicated in other remote, last mile areas of the country.

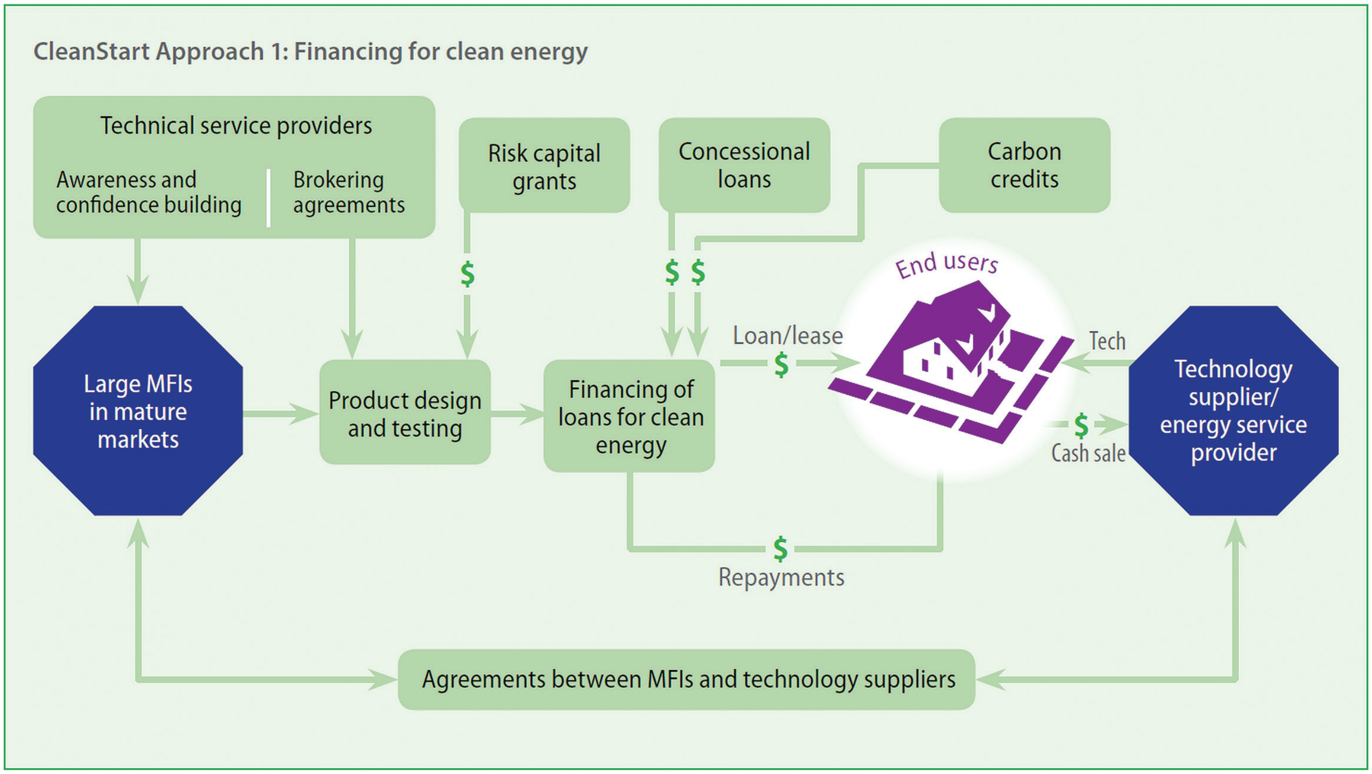
Sources: CONAFE; Feron, Heinrichs, and Cordero 2016b.

The goal of this financing model is to reach rural consumers without modern energy services by putting a responsible financial institution at the center of support for private company, MFI, or NGO service providers. This model is appropriate for the LAC region, given that many LAC countries face the challenge of reaching out to very poor customers who live in remote regions. To achieve this goal, it will be necessary for governments to facilitate the participation of both the financial organizations and energy service providers.

This approach assumes that loans or perhaps partial subsidy funds administered by a financial group or specialized subgroup can be used to finance improved biomass stoves. Also, acceptable standards for the stoves or other renewable energy technologies must be in place. In addition, technical assistance funds should be available for publicity campaigns, market development, and preparation of business plans. Furthermore, the MFIs and NGOs must be interested in promoting improved stoves or renewable energy technologies. Finally, households must perceive that the new stoves or electricity technologies make a profound, positive difference their lives.

Summing up, promoting systems using this model involves three sets of actors. The first set comprises

Figure 5-1. CleanStart model for financing clean energy



Source: UNCDF and UNDP 2012.

institutions for managing energy funds that can provide financing or partial subsidies to participating organizations (e.g., retailers, MFIs, or NGOs). Generally, such institutions can also help with technical assistance and establishment of system standards as a requirement of loans. The second set consists of MFIs and NGOs, whose role is to organize demand, provide customer support, and collect loan payments. The third comprises retailers, who sell equipment for cash and provide product guarantees. The advantage of this approach is that all three groups have key roles that play to their strengths. Sometimes these roles can be combined within the same business or institution.

Conclusion

In the process of ensuring access to affordable modern energy for all, the role of LAC governments needs to extend beyond providing financial resources to include more institutional stability.[13] This includes identifying a central institution, such as a financial entity or energy fund, to champion the cause of energy access. This institution would be responsible for quality control, making energy services affordable (not free), and allocating responsibility to participating enterprises for project development and administration. Some countries have made progress, but the challenging work of reaching the poorest populations in quite remote areas without electricity or clean cooking methods remains. Achieving the vision of affordable modern energy for all in the LAC region will require walking a fine line between public-sector support and innovative private-sector solutions.

13. Many individual projects have succeeded in specific locations but have often not been replicable without extensive, and sometimes wasteful, subsidies.

The institutions for delivering central grid electricity in the LAC region are well developed; however, the last mile issue for covering increasingly remote regions is still a problem. Using grid extension institutions to promote these programs is an awkward solution since they focus more on general electricity production and distribution issues. The new focus on remote areas may require a rethinking of the institutions necessary to promote decentralized electrification programs. The programs could possibly be financed by existing energy institutions. But specialized departments or institutions with connections to the private sector and NGOs may be necessary to solve the many problems that will arise from extending electricity to some of the world's most remote regions.

Chapter 6
Moving Forward

The importance of sustainable rural energy for developing country economies should not be underestimated. In recent years, LAC's energy programs have centered on energy-sector reform, with a focus on globalization and market reform. This study underscores how the effects of rural energy cut across multiple, diverse facets of rural life—from income and labor productivity to education and women's health. The problems rural people face in obtaining safe, clean, and reliable energy supplies are not minor inconveniences. On the contrary, they represent a significant barrier to rural economic development and improved social well-being. A multifaceted approach to solving rural energy problems for those remote or underserved populations is not only warranted; it is an essential building block to propel countries well into the twenty-first century.

The past two decades have witnessed many attempts to promote rural and sustainable energy, with mixed results. Electricity grid programs have been extended far into rural areas. Renewable energy efforts, especially the popularization of solar PV, have achieved a remarkable measure of success. Even so, the technical and socioeconomic issues associated with scaling up household and village electrification require capacity building at national and local levels. Donor- and public-sector supported projects that have introduced and popularized improved biomass stoves have yielded only limited success, despite the large potential benefits of sustaining biomass supply and improving human health. Social afforestation programs initiated over the period have run their course. Although biogas programs have enjoyed considerable success, they fall far short of realizing their considerable potential.

The energy poverty issue in rural areas has brought to the forefront the need for better institutional coordination, along with development of new technologies and market development focused on remote and poor regions. With new models for promoting sustainable energy for all, the understanding of what it takes to implement programs aimed at those without modern energy access is not only possible, but achievable. The task will not be easy. It will require the development of effective institutional coordination, combined with market development and appropriate subsidy and pricing policies. Regulations that do not impede the smaller electricity systems from serving people in rural and poor areas will be necessary. The need for action is vital, not only for rural development, but for equitable economic growth within the LAC region.

Sustainable Models for Addressing LAC Electricity Access

Electricity access in LAC is quite advanced compared to other developing regions of the world. Most governments have persisted in supporting both government-run and private electricity companies to provide service to all. With the exception of Haiti and Honduras, most LAC countries have reached the majority of their populations through grid extension. A few decades ago some companies were privatized in an attempt to improve service for electricity consumers. Today the electricity sector faces problems of providing quality service to consumers, but the institutional models for reaching customers is fairly well established.

That said, the traditional electricity companies are not well equipped to reach out to remaining populations without electricity; however, this is not to imply they have no role to play. Indeed, the most successful programs in reaching remote populations have been implemented by the electricity companies. The problem is that remote area electrification is considered a minor part of their business and perhaps even perceived as a public duty or charity as opposed to a commercial business. However, as indicated in the next section, new technologies and innovative business models are emerging to deal with the poorest and most remote populations in LAC.

New Business Models and Technologies Are Available

Many countries in LAC now face the challenge of reaching out to their remaining last mile customers, which are quite expensive to service. Providing such households with electricity will require both technical and policy innovations. On the technical side, extending the grid to remote areas needs to take stock of low-cost ways that have been developed to provide electricity. These include both single-phase and earth-return systems. Even more promising is the emergence of lower-cost renewable energy systems. Solar, wind, biogas, and micro-hydro systems are all becoming viable for delivering high-quality energy, even in remote areas. In recent years, technical designs for both household and community use have become better established. They still cannot deliver low-cost electricity at the same level as grid systems in more densely populated areas, but they are quite appropriate for low-energy demand in remote areas.

The well-known problem in such areas is that, due to low incomes, households cannot afford to pay the up-front costs of decentralized systems. This issue has also been prevalent for grid-based systems, and ways were developed to cover such costs through cross-subsidies or transfers from government budgets. However, working with one electricity company was easier than dealing with many small systems. LAC has been active in developing models for dealing with the subsidy issue. These have included (i) developing a regulatory framework that allows cross-subsidies to renewable energy systems in remote areas, (ii) financing SHSs from a regional development fund through a national power company, and (3) bidding out SHS projects to private companies to minimize subsidies. These examples, along with other such initiatives as energy funds and the UNDP models, may be well-suited to expanding remote area electrification in LAC. Many of these LAC and international initiatives have not been thoroughly studied, and some assessment of the best practices for serving remote areas is warranted.

Such countries as Haiti and Honduras, among others in the LAC region, still have a long way to go in providing universal electricity access for their populations, especially in rural areas. Haiti has a particularly low electrification rate, at just 30 percent. That country not only has an electricity coverage problem; it also lacks the political and institutional capacity to solve many other problems. Despite these difficulties, both international and regional donors should develop and begin implementing a long-term strategy to address energy access issues in that country.

LAC Has Sparse Initiatives on Clean Cooking

To date, energy access in LAC has concentrated mainly on electricity. However, the region also has about 80 million people that depend on solid fuels for cooking. In Haiti, Guatemala, Honduras, and Nicaragua, more than half of all households use wood, charcoal, and other biomass fuels for cooking. These solid fuels are burned quite inefficiently in primitive stoves. Thus, LAC needs to address the household cooking fuel issue through a strategy that promotes both modern cooking fuels (e.g., LPG and electricity) and the design and dissemination of clean-burning, fuel-efficient solid fuel–fired stoves. In the effort to reach last mile households with electricity, the issues of indoor air pollution (IAP) and the inconvenience of using solid fuels for cooking should not be overlooked.

Such countries as Peru and Honduras, among others, have embraced changes in cooking practices to ensure that their populations have access to cleaner methods of cooking. However, most initiatives have been scattered and incomplete. More work is necessary on the evaluation of existing programs, including their effectiveness and sustainability and the durability of stoves. With the implementation of energy-fund models for promoting electricity in the most remote areas, the agencies in charge of such funds could also be given the mandate to implement clean cooking solutions in their respective countries.

Project Impact Evaluation and Justifying Subsidies

Evaluation of projects is a key to improving their impact and reaching the right populations. This is especially true when projects are moving from promoting electricity with well-established methods to ones that are new and innovative. For these projects, it will be necessary to reach the more remote populations who, no doubt, will require more decentralized energy systems. The development of standard methods for evaluating energy access will be important for understanding consumer satisfaction and problems associated with the new approaches needed to each poor or remote populations.

To justify subsidies, which are commonly necessary to make modern energy systems affordable for poor households, it is essential to understand the impact that investments in energy access will have for the intended populations. The many welfare benefits include better lighting, more motive power, and higher levels of education. At the same time, it is important to understand the complementary inputs necessary to optimize the investments in energy access.

Some countries in LAC require economic feasibility studies to justify the financing of projects. The application of project evaluation techniques, such as consumer surplus and regression-based models, can be used to assess the benefits of energy access projects. These techniques require a specific type of survey in order to quantify project benefits (Barnes and Samad 2017). The deeper study of the impact of energy access for development outcomes can lead the way to providing guidelines on the most important benefits.

Looking Ahead

The international community has been developing a new consensus on measuring energy poverty. The international trend is to go beyond measuring simple access to energy as the main indicator of energy poverty. The new approaches, including the Energy Development Index (EDI) and the Multitier Framework, go beyond simple access to measure the quality of energy services, including reliability, affordability, and other measures. In LAC, the percentage of households with electricity is quite high, but the region has not been as active in measuring the quality and impact of both electricity service and cooking energy.

New approaches to conducting impact evaluation of sustainable energy access in LAC may also be instrumental in determining which programs or projects have the best chance of providing quality energy services to regional populations. A variety of new ways to promote access to modern energy have become both prevalent and necessary for reaching remote areas where grid-based distribution is expensive. These new programs and technologies are promising, but little research has been conducted to evaluate their effectiveness or impact. This is not to imply there should be a pause in efforts to provide sustainable energy for all. On the contrary, it means that proper evaluations are necessary to guide such programs in order to reach the largest number of people and have the greatest impact for poor and remote populations.

LAC has come a long way in providing both grid and off-grid electricity services. In Peru, SHSs are being marketed by qualified private companies with subsidies from existing electricity customers. In Chile, a regional development fund provides grid electricity companies with financing for stand-alone SHSs. Households pay a minimum charge for electricity, and regional companies are provided support for system operation and maintenance. In Ecuador, a public service law now allows a wide variety of businesses to promote electricity for remote populations. For one SHS project, subsidies were justified based on a better analysis of electricity benefits. These and many other new initiatives in LAC offer examples for future projects seeking to reach out to people in poor and remote regions.

However, the lessons from these experiences need to be institutionalized and broadly applied. The many diverse models that have been used to provide electricity to remote populations have often been limited to pilot or small-scale programs. To move forward, significant monitoring and evaluation (M&E) of projects will be required. While the expansion of LPG use in LAC has been remarkable, many people still rely on primitive stoves and firewood for cooking. A concerted effort is needed to continue the expansion of LPG and other modern cooking methods. With 80 million people still using solid fuels for cooking, it is imperative to address the health and other issues associated with the inefficient use of fuel and IAP (e.g., through establishing agencies to qualify better stoves and promote access to clean cooking).

Over the past two decades, the LAC region has made remarkable progress toward providing sustainable, modern energy for all. Today most people in the region have access to the benefits of modern energy. The daunting challenge now facing many LAC countries is how to provide electricity and clean cooking solutions to their most remote and poorest populations. The road ahead will be difficult, requiring innovative financial and institutional approaches rather the traditional methods of the past. This is not the time to rest on past accomplishments. Rather, the task ahead is to reach out to those who still lack the means for improving their lives and engaging in the future.

Annex

Details of the Energy Development Index, International Energy Agency

Table A-1. Details of the Energy Development Index for selected LAC countries

Country	EDI	Electricity access			Clean cooking	House-hold	Community		
		%	Consump-tion	Index	% modern fuels	Index	Public service electricity consump-tion	Share pro-ductive use	Index
Haiti	0.12	0.20	0.01	0.04	0.05	0.05	0.01	0.40	0.20
Guatemala	0.23	0.80	0.15	0.35	0.05	0.20	0.16	0.39	0.27
Nicaragua	0.25	0.72	0.13	0.30	0.03	0.17	0.10	0.57	0.34
Honduras	0.32	0.80	0.25	0.44	0.04	0.24	0.22	0.57	0.40
Guyana	0.37	0.78	0.19	0.38	0.15	0.27	0.09	0.86	0.47
Peru	0.40	0.86	0.22	0.44	0.20	0.32	0.13	0.82	0.48
Paraguay	0.41	0.97	0.38	0.61	0.07	0.34	0.20	0.77	0.49
El Salvador	0.42	0.92	0.23	0.46	0.34	0.40	0.11	0.78	0.45
Bolivia	0.43	0.80	0.16	0.35	0.43	0.39	0.10	0.85	0.47
Dominican Republic	0.47	0.97	0.38	0.61	0.46	0.53	0.09	0.71	0.40
Colombia	0.54	0.97	0.36	0.60	0.44	0.52	0.24	0.87	0.55
Jamaica	0.54	0.92	0.35	0.57	0.23	0.40	0.43	0.94	0.69
Panama	0.58	0.88	0.49	0.66	0.35	0.50	0.48	0.85	0.66
Ecuador	0.59	0.92	0.32	0.54	0.75	0.65	0.19	0.89	0.54
Costa Rica	0.61	0.99	0.62	0.79	0.14	0.46	0.61	0.90	0.76
Cuba	0.62	0.97	0.51	0.70	0.44	0.57	0.43	0.92	0.68
Brazil	0.68	0.99	0.48	0.69	0.46	0.57	0.59	0.99	0.79
Uruguay	0.69	0.99	0.90	0.94	0.37	0.66	0.57	0.88	0.72
Argentina	0.82	0.97	0.72	0.84	0.97	0.90	0.62	0.86	0.74
Venezuela	0.83	1.00	0.71	0.84	0.82	0.83	0.67	1.00	0.83

Source: IEA 2012.

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