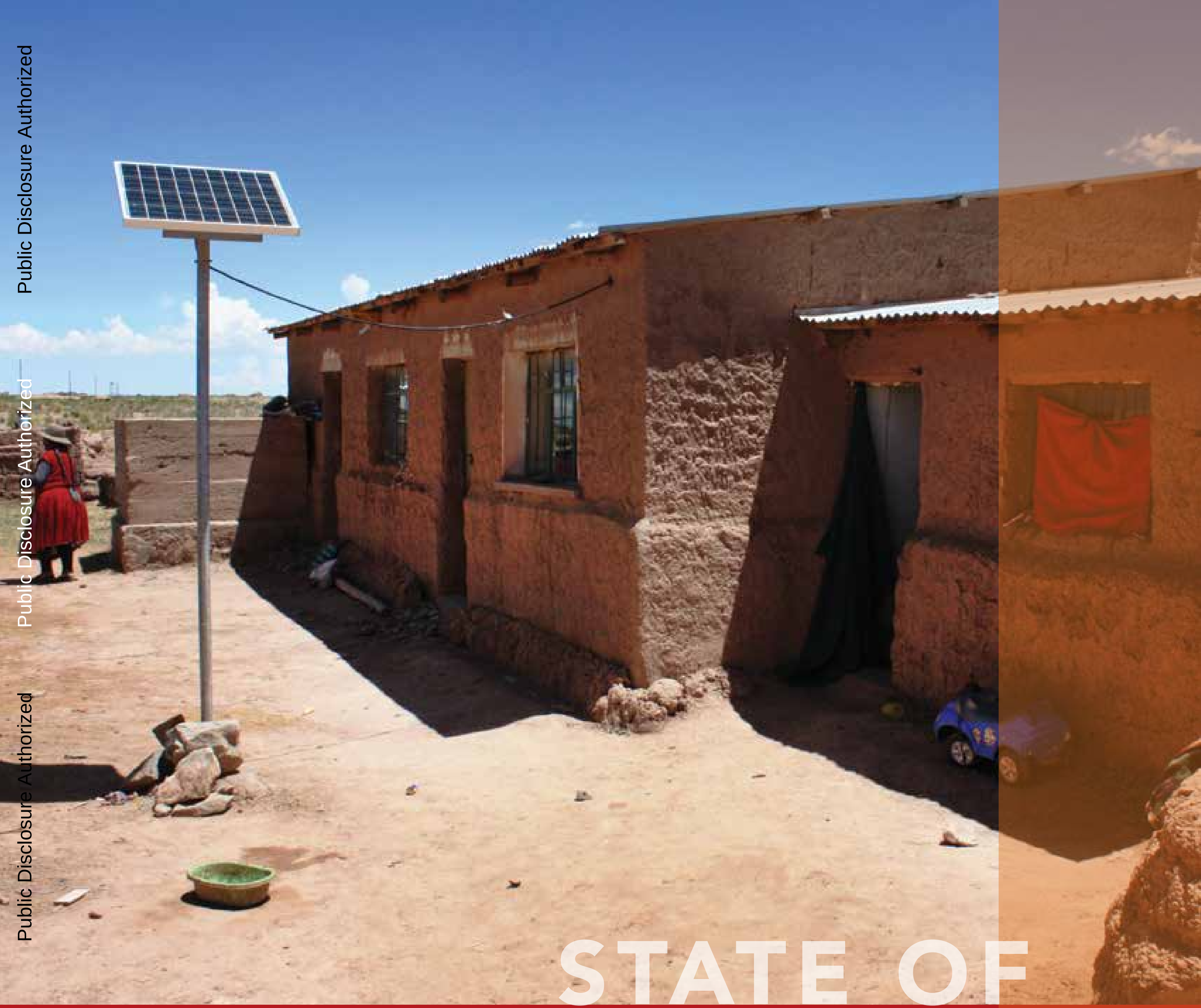

STATE OF ELECTRICITY ACCESS REPORT

2017

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STATE OF ELECTRICITY ACCESS REPORT 2017

WORLD BANK GROUP

ESMAP
Energy Sector Management Assistance Program

SUSTAINABLE ENERGY FOR ALL

SEAR

CONTENTS

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African Development Bank (AfDB)
Asian Development Bank (ADB)
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Food and Agricultural Organization (FAO),
Inter-American Development Bank (IDB)
International Network on Gender and Sustainable Energy (ENERGIA)
Kreditanstalt für Wiederaufbau (KfW)
Practical Action
Renewable Energy Policy Network for the 21st Century (REN21)
Sustainable Energy for All (SEforAll)
United Nations Foundation (UNF)
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PREAMBLE

The World Bank's Energy Sector Management Assistance Program (ESMAP) committed to delivering the "State of Electricity Access Report (SEAR)" project as part of the Sustainable Energy for All (SE4ALL) Knowledge Hub activities. The SEAR is intended to complement the Global Tracking Framework (GTF) Report series, the work on the Multi-Tier Framework, and the recently launched Regulatory Indicators for Sustainable Energy by serving as a periodical stocktaking of the status and nature of progress on the target of ensuring universal access to affordable, reliable, modern energy services by 2030.

The SEAR 2017 begins with an examination of the critical role of electricity access toward the achievement of the SDGs, then provides a snapshot of the status of electricity access based on the recent Global Tracking Framework Data (IEA and World Bank, 2017). It goes on to explore how countries can create a conducive environment for a transformative electricity access roll out, how clean energy fits into the picture, and how emerging and innovative service delivery models can accelerate progress on meeting the goals.

Its objective is to prompt governments, donors, the private sector, civil society organizations, and practitioners to develop interventions to close the electricity access gap by integrating lessons learned from countries that have expanded electricity access to their population, with insights drawn from emerging innovative business and delivery models.

The SEAR 2017 is articulated around five main questions:

- Why is electricity access critical for the achievement of the 2030 Agenda for Sustainable Development?
- What is the status of electricity access?
- What are the challenges and drivers of transformative electricity access?
- Why is it important to explore synergies between access, renewables, and energy efficiency?
- What are the emerging and innovative business and delivery models?

The Report is organized as follows:

AN OVERVIEW of the main topics discussed in the report, highlighting key messages.

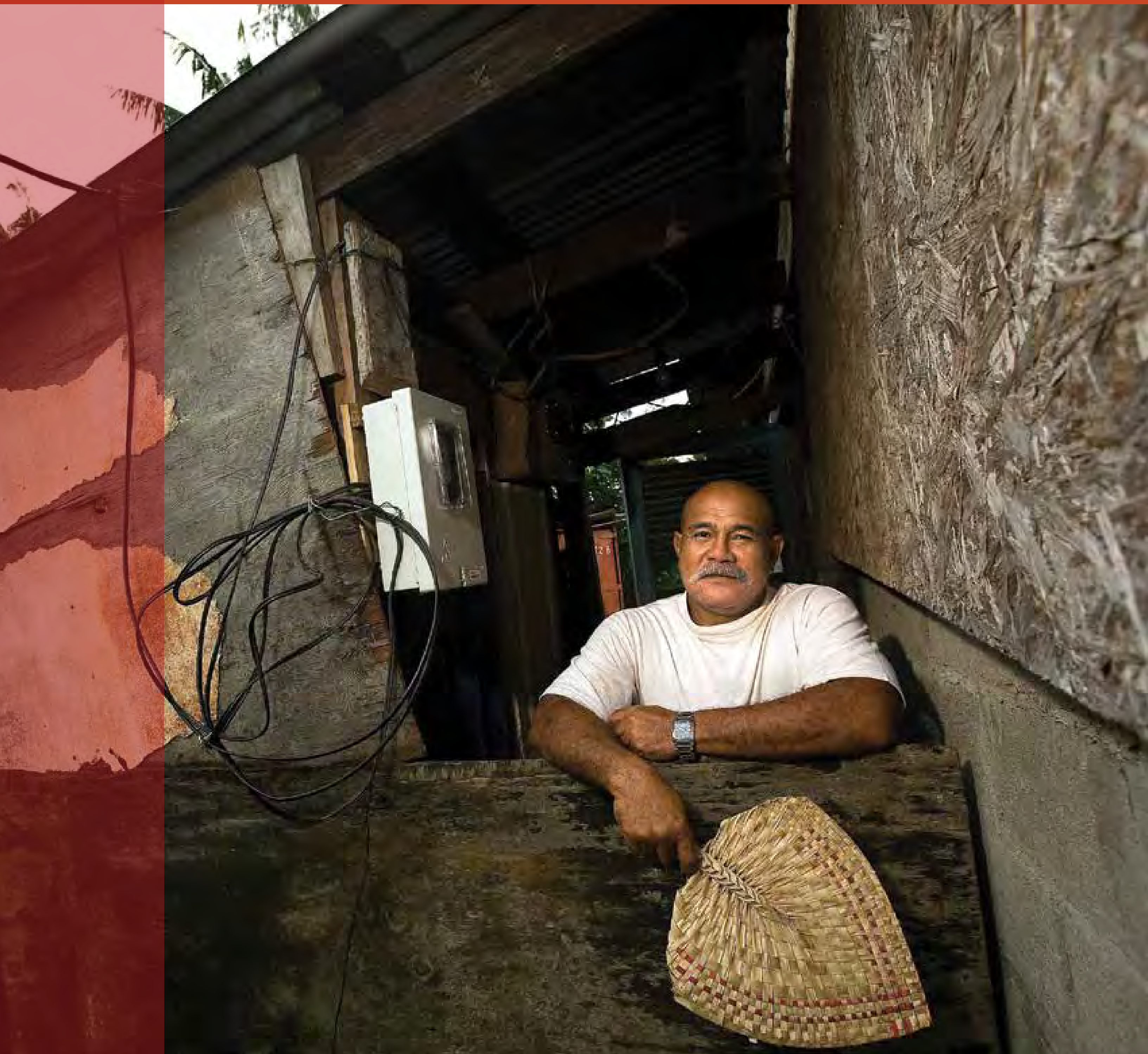
CHAPTER 1: The Case for Universal Electricity Access. The first chapter demonstrates why energy is important for sustainable development, and how ensuring universal access to affordable and reliable modern energy services can contribute to reducing poverty, promoting human development, and increasing economic growth.

Chapter 2: The Status of Electricity Access. This chapter provides an updated snapshot of the status and trends of electricity access, highlighting the scale of the challenge ahead— including measurement issues. It is largely derived from the methodology adopted by the 2017 Global Tracking Report.

CHAPTER 3: Creating a Better Environment for Transformative Electricity Access. This chapter explores the key factors in designing and implementing successful electricity access programs. It covers challenges in expanding grid electrification and developing off-grid electrification— along with how to plan for a complementarity of grid and off-grid electricity solutions. It also highlights policy, regulation, technical, and financing factors.

CHAPTER 4: "Clean Energy" and Electricity Access. This chapter discusses the significant role that clean energy— that is, renewable energy and energy efficiency— could play in meeting the electricity access challenge. It focuses on what is unique about clean energy in overcoming energy poverty, along with when and how clean energy can help provide modern energy services more quickly, more reliably, in an environmentally safer manner, and at a lower cost than fossil fuel alternatives.

CHAPTER 5: Emerging and Innovative Business and Delivery Models. This chapter illustrates several cases where new delivery models, financing mechanisms, and policy and regulation instruments have been put in place to provide energy services. It draws examples from grid and off-grid interventions. It discusses the market opportunity presented by the electricity access challenge and how several stakeholders are meeting it in practice. And it outlines the main risks and challenges perceived by investors and incentives that are necessary to attract investment.



OVERVIEW

KEY MESSAGES

- Given current conditions, universal electricity access will not be met by 2030 unless urgent measures are taken. While nearly 1 billion people in Sub Saharan Africa alone may gain electricity access by 2040, due to population growth, an estimated 530 million people in the region will not have electricity access (IEA 2014).
- This energy shortfall must be rectified if the international community hopes to meet the 2030 Sustainable Development Goals, in light of the linkages between energy and other sustainable development challenges—notably, health, education, food security, gender equality, poverty reduction, and climate change.
- In many countries with low levels of electrification access, both grid and off-grid solutions are vital for achieving universal electricity access—but they must be supported by an enabling environment with the right policies, institutions, strategic planning, regulations, and incentives.
- Against a backdrop of climate change, plummeting costs for renewable energy technologies and adequate energy efficiency measures offer a tremendous opportunity for countries to be creative about electricity access expansion—with the emphasis on "clean energy."
- Emerging and innovative energy service delivery models offer unprecedented opportunities for private sector-driven off-grid electrification and accelerating universal electricity access—but only if countries can create the necessary environment for them to be replicated and scaled up.

INTRODUCTION

Without access to electricity, the pathway out of poverty is narrow and long. The current pace of progress is not moving fast enough: 1.06 billion people still do not have access to electricity, and 3.04 billion people still rely on solid fuels and kerosene for cooking and heating (IEA and World Bank 2017). Despite significant progress in recent decades, achieving universal access to modern energy services by 2030 will not be possible without stepped-up efforts by all stakeholders.

In September 2011, the Sustainable Energy for All (SEforAll) initiative was launched with a call for: (i) universal access to modern energy services; (ii) double the global rate of improvement in energy efficiency; and (iii) double the share of renewable energy in global energy production. This call is also one of the 17 UN Sustainable Development Goals (SDGs), which are part of the 2030 Agenda for Sustainable Development, adopted in September 2015. At root is a recognition that energy is a key factor for sustainable development and poverty alleviation, and that it plays an important role in all major development challenges that the world faces.

What can be done to get the international community on track to close the electricity access gap? This report—The State of Electricity Access Report (SEAR) 2017 begins with an examination of the critical role of energy toward the achievement of the SDGs, then provides a snapshot of the status of electricity access, based on the recent Global Tracking Framework Data (IEA and World Bank, 2017). It goes on to explore how countries can create a conducive environment for a transformative electricity access roll out, how clean energy fits into the picture, and how emerging and innovative service delivery models can accelerate progress on meeting the goals.

This report is supplemented by a package of other materials: (i) 10 Special Features that delve into topics ranging from electricity planning, human capital, gender, water, health, food, and agriculture—including in emergencies—to climate change, energy efficiency, and results-based financing (they are summarized at the end of this overview); (ii) 5 case studies; and (iii) 4 impact evaluation reports.

Its objective is to prompt governments, donors, the private sector, civil society organizations, and practitioners to develop interventions to close the electricity access gap by integrating lessons learned from countries that have expanded electricity access to their population, with insights drawn from emerging innovative business and delivery models. The SEAR is organized around five main questions:

- Why is electricity access critical for achieving the 2030 Agenda for Sustainable Development?
- What is the status of electricity access?
- What are the challenges and drivers of transformative electricity access?
- Why is it important to explore synergies between access, renewables, and energy efficiency?
- What are the emerging and innovative business and delivery models?

The key findings of the *SEAR Report 2017* are that urgent measures are needed to speed up access to modern energy services or there will still be several countries in 2030, mostly in Sub-Saharan Africa, with a significant percentage of the population going without. Both grid and off-grid approaches will be critical, but they will have to be supported by a conducive enabling environment of the right institutions, policies, strategic planning, regulations, and incentives. The good news is that lower costs for renewable energy technologies and adequate energy efficiency measures should make it possible for countries to be creative in meeting this challenge and put the emphasis on "clean energy"—that is, renewable energy and energy efficiency. There is also a growing role for the private sector to finance interventions, assuming the incentives are in place for investors to earn returns on their investments.

WHY IS ELECTRICITY ACCESS CRITICAL FOR ACHIEVING THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT?

For the international community, there is broad agreement that access to modern energy services is a necessary pre-requisite for alleviating poverty and boosting shared prosperity. Without energy, it is challenging, if not impossible, to promote economic growth, overcome poverty, expand employment, and support human development. Sustainable energy is the seventh goal of the 17 UN Sustainable Development Goals (SDGs), with a call to "ensure access to affordable, reliable, sustainable and modern energy for all." Its five targets indicate areas where policies can be designed—such as boosting the share of renewable energy in the global energy mix and doubling the global rate of improvement in energy efficiency (Box O.1).

Furthermore, energy can contribute to achieving the other 16 SDGs (Figure O.1). A review of all SDG targets indicates that energy is interconnected with 125 (74 percent) out of the 169 targets, making it crucial for all societies to recognize the key interlinkages of energy and the wider development agenda (Vera, 2016). Thus, planning for universal access to modern energy services should be an integral part of national planning efforts to achieve the SDGs. Studies of power outages indicate that lack of energy does lead to a loss of output at a firm level—for example, in 2013, the World Bank Enterprise Surveys showed that power outages in Tanzania cost businesses about 15 percent of annual sales—and greater availability of energy has been shown to lead to more income, jobs, and educational benefits at the individual household level. In addition, lack of access to modern energy (especially grid electricity) acts as a constraint on economic growth, while access to modern energy services can stimulate growth and employment opportunities.

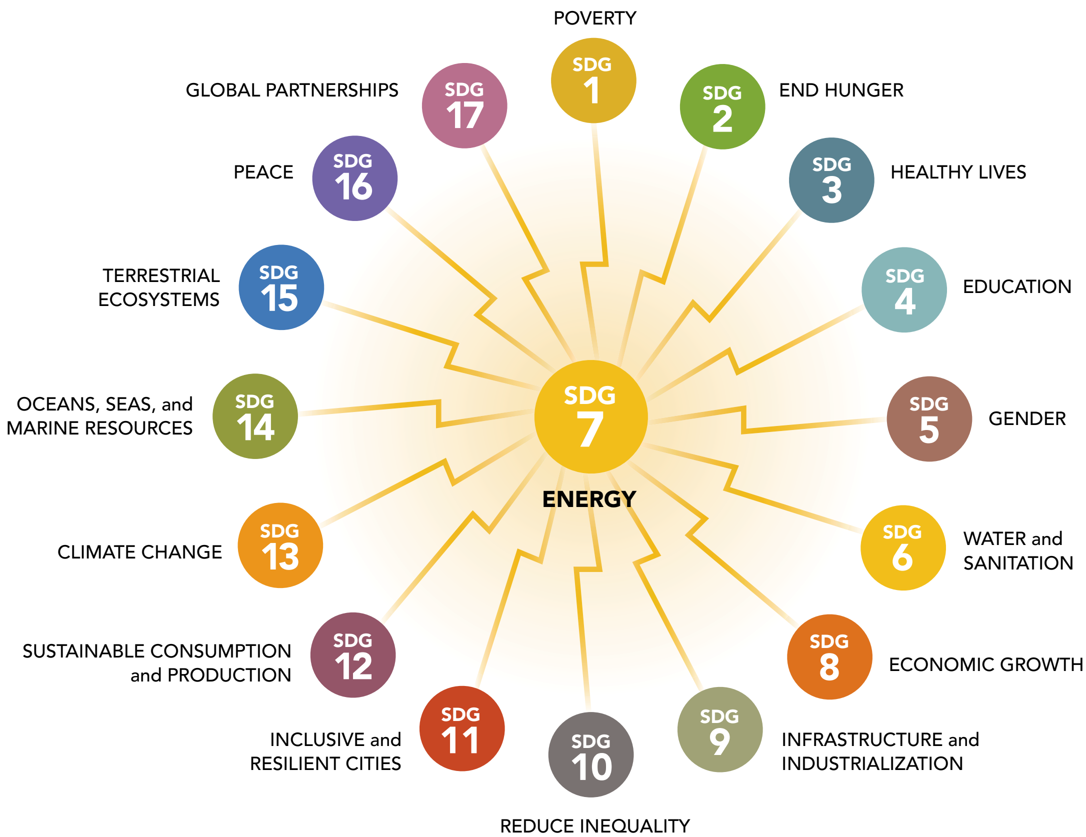
BOX O.1

Targets for Sustainable Development Goal 7

- By 2030, ensure universal access to affordable, reliable and modern energy services
- By 2030, increase substantially the share of renewable energy in the global energy mix
- By 2030, double the global rate of improvement in energy efficiency
- By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, Small Island Developing States, and land-locked developing countries, in accordance with their respective programs of support

Source: UN 2016.

FIGURE O.1 Energy is linked to all the remaining Sustainable Development Goals



Countries with the highest levels of poverty tend to have lower access to modern energy services—a problem that is most pronounced in Sub-Saharan Africa and South Asia, where a large share of the population depends on traditional biomass for cooking and heating and lacks access to electricity. Poor households lack the resources to purchase modern energy services (especially when there is a connection charge to obtain the modern energy source, as with electricity). At the same time, households lacking access to electricity and other modern energy sources have fewer opportunities for income generation (especially from agriculture). These households earn less, spend more time collecting biomass and less time on education, and pay more per unit for the limited amounts of modern energy that they can purchase (such as batteries for lighting and phone charging).

In addition, households using solid fuels and traditional cooking methods are subject to high levels of indoor air pollution, which is associated with high rates of mortality and morbidity, especially for women and children who have the greatest exposure to this pollution. Access to modern energy services, either through the form of advanced combustion cook-stoves using biomass, or through a switch to the use of LPG, can substantially reduce the long-term costs to the household from diseases associated with high levels of indoor air-pollution. Several studies estimating the benefits of electrification on households or small businesses suggest that electrification results in higher household income, with the magnitude varying considerably among countries. In Bhutan, non-farm income increased by 63 percent, while farm income was unaffected (Kumar and Rauniyar, 2011), and in India, non-farm income rose by 28 percent (Khandker et al., 2012). However, recent studies also show that the benefits of electrification can be overestimated if the endogeneity of a household is ignored—that is, electrification does not only affect income but income can also determine whether or not a household is electrified. For example, higher-income households are more willing to get a connection as soon as the grid arrives (particularly if the connection fees are not fully subsidized), and utilities prefer to provide electricity to higher-income communities (Bacon and Kojima 2016).

As for the environment, the link between energy and climate change is twofold. The energy system is a major contributor, as it generates greenhouse gas (GHG) emissions through energy production and use, while climate change can disrupt the world's energy system—as extreme weather events, sea level rise, water availability changes, and temperature increases affect supply and demand of energy. It is particularly challenging to estimate future impacts of the energy sector on climate change, as multiple factors are coming into play. Fortunately, the goal of achieving universal access to modern energy services in itself would result in a negligible increase of carbon dioxide (CO_2) emissions if the energy demand of the affected population is projected to remain low. However, as people emerge from poverty, demand for energy will increase, and power system planning will have to account for spillover effects.

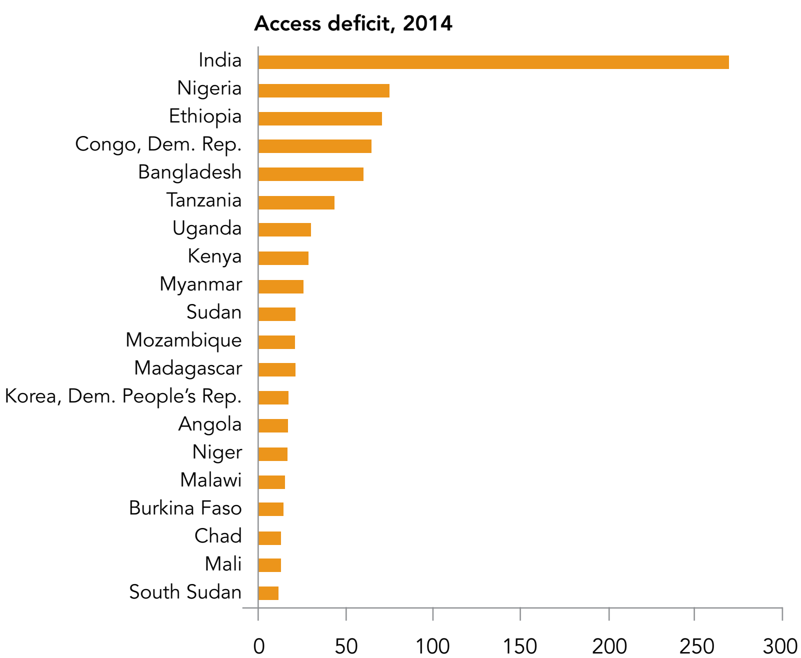
In sum, there are many opportunities for access to modern energy services to contribute to achieving the other SDGs if interventions are designed to operationalize the linkages between electricity access and other sustainable development challenges—such as health, education, food security, gender equality, poverty reduction, and climate change.

WHAT IS THE STATUS OF ELECTRICITY ACCESS?

In 2014, 1.06 billion people still lived without access to electricity—about 15 percent of the global population—and about 3.04 billion still relied on solid fuels and kerosene for cooking and heating (IEA and World Bank 2017). The electricity access deficit is overwhelmingly concentrated in Sub-Saharan Africa (62.5 percent of Sub-Saharan Africa population) and South Asia (20 percent), followed by East Asia and the Pacific (3.5 percent), and Latin America (3 percent) and the Middle East and North Africa (3 percent). In Sub-Saharan Africa, 609 million people (6 out of 10) do not have access to electricity, and in South Asia, 343 million people do not have access to electricity.

At the country level, India alone has a little less than one-third of the global deficit (270 million for electricity), followed by Nigeria and Ethiopia for electricity—and the 20 highest access-deficit countries for electricity account for 80 percent of the global deficit (Figure O.2).

FIGURE O.2 India has the world's largest electricity access deficit
(Top 20 countries for access deficit in electricity, 2014)



Source: IEA and World Bank 2017
Note: These countries account for more than 81 percent of the global access deficit.

Between 2000 and 2014, there were advances in electrification, with the global electricity deficit declining from 1.3 billion to 1.06 billion—and the global electrification rate rising from 77.7 percent to 85.5 percent. Progress with rural electrification is evident, with the global rural electrification rate increasing from 63 percent in 2000 to 73 percent in 2014. Urban areas across the world are already close to universal access at 97 percent. Although urban access rates have risen relatively little in the past 25 years, this level remains a major achievement when viewed against the rapid urbanization that has brought an additional 1.6 billion people into the world's cities during this period.

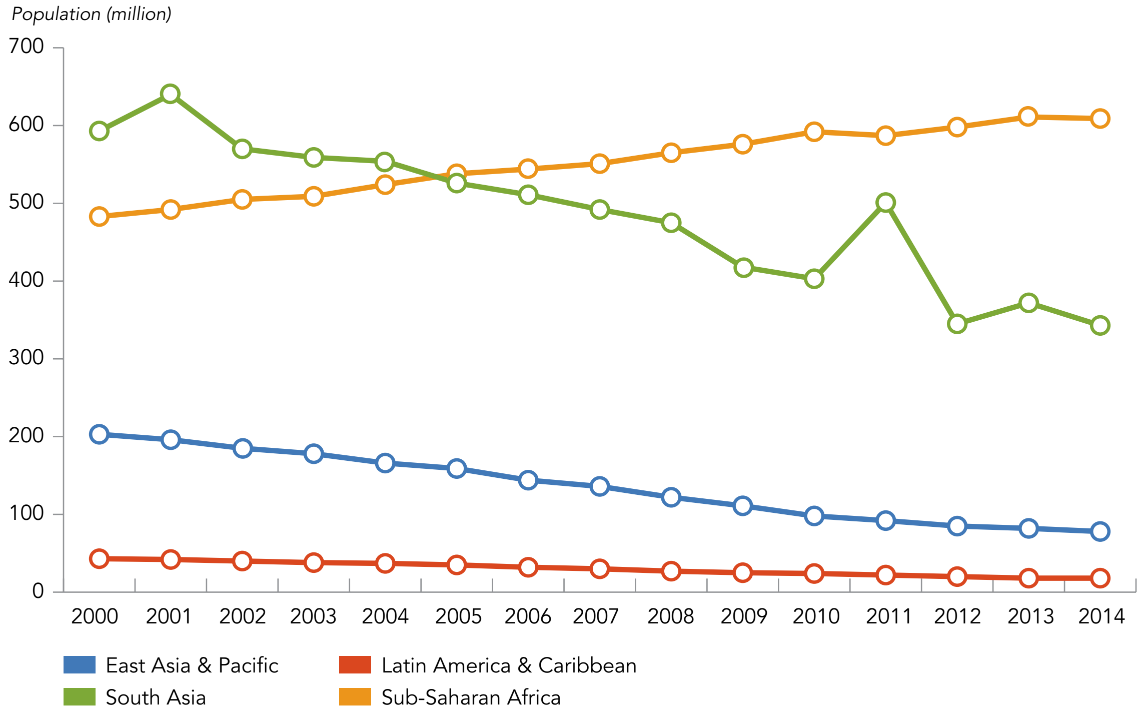
Among the regions, improvement in access to electricity in the period 2000–14 has been remarkable in South Asia (rising from 57 to 80 percent), in other regions growth during the same period has been moderate: for East Asia and Pacific (from 90 to 96 percent), Middle East and North Africa (from 91 to 97 percent), Latin America & Caribbean (from 92 to 97 percent) and Sub-Saharan Africa (from 26.5 to 37.5 percent). Trends in population lacking access to electricity are rising in Sub-Saharan Africa, where 609 million people still do not have access to electricity services. (Figure 0.3).

How much improvement will be needed to get the world back on track? Progress has fallen consistently short of the population growth rate since 2010, meaning that efforts in the remaining years will need to be stepped up to 0.9 percent for electricity (Figure O.4). At the regional level, Latin America, East Asia, and South Asia will be able to reach universal access by 2030, assuming conditions of constant growth in electricity, constant growth in population, and no major changes in political willingness and financial investments in increasing access. However, Sub-Saharan Africa is falling behind—currently growing at 5.4 percent annually against the needed 8.4 percent annually to reach universal access by 2030.

Although the access deficit in 2014 for electricity was overwhelmingly rural, the expected population growth of 1.5 billion by 2030 will be almost entirely urban, reflecting rural-urban migration. This implies that the number of rural households for which access needs to be created will stabilize and not be inflated by population growth. Although urban connections may be perceived as lower cost and therefore easier to implement than rural connections, the challenges presented by urban slums require regulatory and financial incentives to ensure that universal access is attained. A further challenge is presented by the recent spread of the "rapid growth of households" from developed countries to developing countries (Badger 2014, Bradbury, Peterson, and Liu 2014).

What is the anticipated price tag for closing the gap? A 2011 study by IEA on comparable estimates of current financing trends and future investment needs for achieving universal access to electricity provides a high-level estimate of investment needs of $45 billion a year, against actual investment flows at that time of an estimated $9 billion a year (IEA 2011).

FIGURE O.3 Sub-Saharan Africa is not keeping up with population growth for electricity access
(Trends in population lacking access to electricity, 2000–2014)

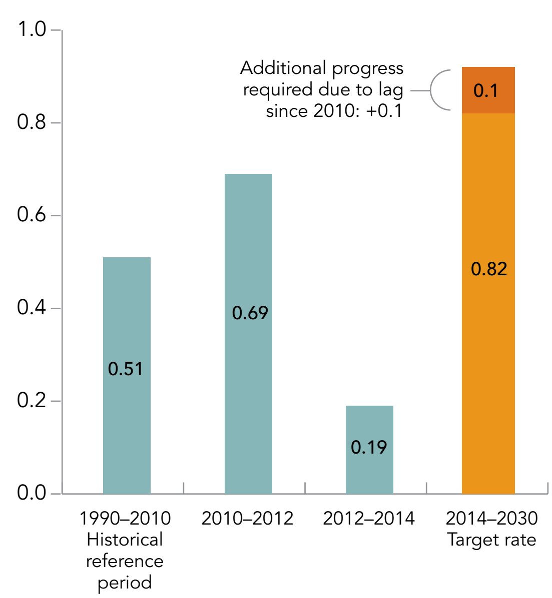


Source: Data from IEA and World Bank 2017

The World Bank's Access Investment Model provides detailed bottom-up estimates of the cost of reaching universal access in each of 15 countries with large electricity access deficits. These countries reflect differences in population and geography as well as local unit costs, and they can be used to give a global estimate of access investment needs (IEA and World Bank, 2015). The model, based on the Multi-Tier Framework, allows users to choose the tier of access that would be used to meet the universal access target, and illustrates how dramatically this affects the costs of electrification. Reaching universal access at Tier 1 (enough to light a few light bulbs and charge a mobile telephone) would require investments of $1.5 billion annually up to 2030. By contrast, reaching universal access at Tier 5 (full 24x7 grid power) would require investments of $50 billion annually.

In sum, universal electricity access will not be met by 2030, unless urgent measures are taken. While nearly 1 billion people in Sub Saharan Africa alone may gain electricity access by 2040, due to population growth, an estimated 530 million people in the region will not have access (IEA 2014). One tool that would help facilitate the effort would be a new way of measuring the electricity access target, beyond the traditional binary metrics—which can be misleading because they do not capture the multi-dimensionality of electricity access. The World Bank and ESMAP are working with partners to promote broader adoption of the Multi-tier Framework as the key monitoring platform for tracking progress toward SEforAll and SDG 7.

FIGURE O.4 Electricity access falls short of the pace to meet the 2030 target



Source: IEA and World Bank 2017

WHAT ARE THE CHALLENGES AND DRIVERS OF TRANSFORMATIVE ELECTRICITY ACCESS?

More than 70 countries have been working over the last four years to develop action plans, strategies, and projects to deliver on the goal of universal access to modern energy services. Their efforts have been supported by partnerships and initiatives from both the public and private sector that have emerged at the national, bilateral, and multilateral levels.

For electricity, meeting the demand created by increased access follows two main tracks: (i) grid-electrification providing connections to urban, peri-urban, and rural areas; and (ii) off-grid electrification through community level micro- or mini-grid systems, or isolated devices and systems at the household level. These two approaches have different capital requirements, serve different population densities, and use different technologies.

The expansion of national electricity grids, which is the "conventional" method for broadening access, involves adding power plants and extending high-voltage transmission lines and distribution networks into rural areas. In the past two decades more than 1.7 billion people have been added to national electricity networks worldwide, mostly in urban areas. Although progress has also been made in rural areas, the numbers are not rising as fast, because rural grid electrification programs involve connecting villages incrementally to the existing grid, with remote areas with small populations, high line losses, and low usage usually the last to be connected.

The biggest challenges to expanding grid-based electrification and access are the lack of sufficient generation capacity, poor transmission and distribution infrastructure, the high costs of supply to rural and remote areas, the inability of low income households to pay high connection charges, and the weak financial state of the utilities. The investment needs for a program to expand access to rural areas are large, while the possible receipts are likely to be insufficient to cover costs without financial support. A very substantial barrier to household access is the cost of connection. In Africa, unsubsidized connection costs often exceed the country's monthly income per person, and households have to pay these plus fees for inspection and application, security deposits, internal wiring, and equipment costs. These fees are usually charged upfront making it difficult for low income households to afford the service.

Energy services can also be expanded using "off-grid" electrification, which involves much smaller grids than in grid electrification. One approach is "mini-grids"—isolated groups of generation, distribution, storage facilities within a confined geographical space. They are usually locally managed, have less than 10 MW of installed capacity, serve small household loads, and serve an area of up to 50 kilometers radius. Another approach is "micro-grids"—smaller units, typically operating with less than 100 kW of capacity, at lower voltage levels, and covering a radius of up to 8 kilometers.

Both of these can be powered by fossil fuels (diesel) or by renewables (hydro, solar PV, biomass combustion, and wind). Hybrid systems using renewable energy sources together with batteries or a diesel generator can be used to address the problems of intermittency. In very remote communities, energy services can be provided by off-grid units, such as PV solar home systems or pico-solar products. These can be deployed faster and more simply than a mini-grid.

What is holding up progress? The key hurdle appears to be creating an enabling environment for an electricity access roll out. While no single recipe exists, the evidence points to the need for the right policies, institutions, strategic planning, regulation, and incentives as vital prerequisites.

For rapid grid-based expansion, lessons from successful countries suggest the following main drivers: (i) there needs to be a sustained government commitment over a long period of time; (ii) there should be dedicated institutions to plan, implement, and expand electrification programs; (iii) there should be predictable financing mechanisms to support public sector programs and to attract private sector initiatives; and (iv) measures should be adopted to ensure the affordability of electricity services.

For developing off-grid schemes, mini-grids offer a means of supplying "grid-quality" power to communities quickly without having to wait many years for the grid-based distribution network to reach distant communities. However, there are challenges to be met in order to ensure that mini-grids are the least-cost solution and continue to provide affordable electricity services over the long-run, and that key risks are mitigated to offer viable business opportunities. High upfront investment requires anticipated load growth to materialize, or else there will be inadequate revenues to cover costs. Mini-grids tariffs are usually higher than grid-based tariffs (unless there is a significant subsidy to the mini-grid), which may limit the willingness-to-pay of households.

Where both grid and off-grid solutions are being developed, it is important to ensure complementarity of these solutions. For example, if the grid reaches the mini-grid service area, demand for mini-grid services would decline sharply and the investment in the stranded assets would become unrecoverable, in the absence of special policies to address this issue. Often, off-grid solutions are developed in geographic areas far from the grid to provide communities with electricity services sooner than the grid. Take the case of Cambodia, where, as a study by Tenenbaum et al. (2014) explains, there was a lack of policy on what to do when the grid reached the mini-grids. Eventually, the situation was resolved by the regulator issuing licenses to transform the mini-grids into distribution utilities—but it underscores the need for planning upfront for the eventual arrival of the grid to give investors more confidence to develop mini-grids in rural and remote areas. The study recommends four options for when the grid arrives:

- Small Power Distributor (SPD) Option where the Small Power Producer (SPP) operating a mini-grid converts to distributor that buys electricity at wholesale from the national grid and resells it at retail to its local customers.

- SPP Option where the mini-grid operator sells electricity to the operator of the national grid but no longer to its local customers.
- Buyout Option where the SPP sells its distribution grid to the national grid operator or other entity designated by the regulator and receives compensation for the sale of the assets.
- Combined SPP and SPD Option where the SPP converts to an SPD and also maintains a backup generator as a supply source to the main grid and retail customers.

As part of the planning process, it is essential to choose the right technology to provide the electricity, whether to urban or remote rural areas, in a cost-effective manner. That is where geographical information system (GIS) models—which enable the assessment of the cost of electricity provision and energy cost implications of competing technological systems in space and time—fit in (Howells et al., 2017). In addition, for electricity access programs to be transformative, special attention needs to be paid to productive uses of electricity services—defined as agricultural, commercial, and industrial activities that require electricity services as direct inputs to the production of goods or provision of services (EUEI PDF 2011; Short 2015; Contejean and Verin 2017). Rural and remote areas, which are often inhabited by low-income households and lack electricity supply, may not have opportunities to expand productive uses even if electricity is made available. In those cases, complementary initiatives—such as facilitation for micro-finance and vocational training—may be needed to both maximize the benefits of electricity programs and promote long-term sustainability.

In sum, while recognizing that each country will have to decide on its own pathways to universal access, sustainable government commitment will be essential, as occurred in Vietnam (Box O.2). Also vital will be making modern energy provision part of a broader vision of social and economic transformation. In many countries with low levels of electrification access, they will need both grid and off-grid solutions—supported by an enabling environment with the right policies, institutions, strategic planning, regulations, and incentives.

WHY IS IT IMPORTANT TO EXPLORE SYNERGIES BETWEEN ACCESS, RENEWABLES, AND ENERGY EFFICIENCY?

Meeting the global target for electricity access while achieving the Paris Agreement's goal of limiting global warming to below 2˚C will require a major shift toward "clean energy"—that is, renewable energy and energy efficiency. Supply from renewable energy technologies is now growing at an unprecedented rate, while the growth in the global economy is starting to decouple from energy-related carbon emissions, thanks to the adoption of energy efficient measures and technologies.

Since 2013, the world has added more renewable energy power capacity (an estimated 147 GW by end 2015) than conventional capacity, while investment in renewable power and fuel in developing countries in 2015 surpassed that in developed countries. Energy efficiency and technology reduced the growth of global final energy demand by almost two thirds (0.7 percent increase as opposed to the previous decade's average 2 percent). This growth has been driven by significant reductions in the costs of renewables. In 2014/2015 the median cost of producing baseload power from residential solar was $200/MWh—sharply down from $500/MWh in 2010—compared to about $100/MWh for conventional sources. Wind and solar PV costs were lower, and long-term contracts in some countries were in the range $60-80 for onshore wind, and $80-100 for utility scale solar PV.

As ***renewable energy*** continues to gather momentum, grid integration is emerging as a key issue to accommodate a higher share of renewables. One of the biggest challenges will be coping with the variability and intermittency of modern sources of renewable energy (such as solar and wind)— given that the current grid infrastructure in many countries was built on the basis of controllable energy sources and organized around the generation-transmission-distribution model. The good news is that renewable energy technologies are flexible, modular, and can be used in various configurations, ranging from those that are grid-connected to those that are off-grid.

Mini-grids are emerging as a key player for cost-effective and reliable electrification of rural areas (Figure O.6) . It is projected that one-third of total investments toward achieving universal access by 2030 will be targeted to mini-grids, with the vast majority (over 90 percent) coming from renewable energy generation. Hybridization of mini-grids is increasingly popular, especially in countries that have been powering exiting mini-grids with diesel. Moreover, improvements in storage systems will increase the use of renewables and decrease the share of diesel which would mainly supply evening peaks. Mini-grids can also contribute to the socioeconomic development of a region. Besides providing basic energy services (lighting and phone charging), they can fuel productive activities such as pumping, milling, and processing. A recent comparison of diesel and hybridized mini-grids at seven sites in Africa, Asia, and Latin America, showed potential savings ranging from 12 to 20 percent, depending on oil prices.

It is true that the huge potential for electricity access using mini-grids is hindered by numerous challenges—including inadequate policies and regulations, lack of proven business models for commercial roll-out (notably for pico-solar systems), and lack of access to long-term finance. But many countries are currently developing mini-grid policies to address these problems. India has released a draft national policy for mini and micro grids, which, if adopted, will create the proper framework and environment for developing 500MW capacity over the coming decade. Kenya's Energy Regulatory Commission has licensed Powerhive East Africa Ltd. to generate, distribute, and sell electricity—the first private company in Kenya's history to receive a utility concession. Powerhive will develop and operate solar mini grids of a total capacity of 1MW to power 100 villages.

BOX O.2

Vietnam's National Drive to Achieve Universal Electricity Access

Vietnam's experience demonstrates that where strong political commitment exists, the goal of universal access to electricity is achievable irrespective of the country's starting condition. This commitment, however, needs to go hand in hand with a willingness to learn from past mistakes and correct one's course when circumstances change.

In 1994, when Vietnam started its universal access drive, its electrification rate was only 14 percent, comparable to the access rates of the least electrified countries in Africa. By 1997, the rate had jumped to 61 percent, and by 2002, it was over 80 percent. Today, the Vietnamese population enjoys the full benefits of electricity, with an access rate over 99 percent.

Vietnam's secret to success was not betting on a particular electrification approach, but rather allowing the approaches to evolve over time. In the initial "take-off" phase (1994–97), the goal was to trigger fast access expansion by empowering communities and local authorities to build their own systems. During this phase, little attention was paid to service quality, costs, tariff levels and other regulatory aspects. It was a highly decentralized approach, with a very limited role for the national utility EVN, which was only selling electricity in bulk to these newly created mini-distribution entities. This was a period of extremely fast electrification, with the rate jumping from 14 percent to 61 percent in just three years—as well as record investments leveraged from users, communities and local governments.

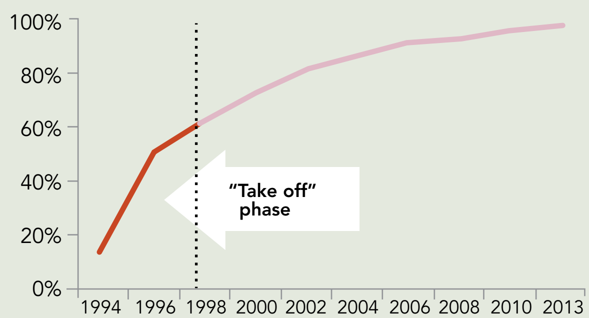
However, there was a trade-off between the pace and the sustainability of the electrification efforts. As it turned out, many new distribution networks were of low technical quality and suffered high losses, and the newly established entities did not have sufficient experience nor the financial strength to operate them. The subsequent phases, therefore, prioritized sustainability measures, with a heightened focus on ensuring service quality and both technical and financial viability. Gradually, the dispersed local electrification networks were consolidated into larger units and their operators corporatized; most of them were eventually absorbed by the national utility, EVN.

While many elements of Vietnam's electrification approach are unique to Vietnam, its key lessons are pertinent to all electrification efforts:

- Vietnam has achieved universal access to electricity largely due to the government's unwavering commitment to electrification, and its willingness to learn and when necessary change course.
- Fast progress and a record fund mobilization was possible by making electrification a national priority, engaging central, regional, and local government, along with rural communities.
- Fast progress is not just a matter of political commitment, it also requires a strong demand and a willingness to pay from the participating population—when rural income rose, electrification took off.
- The trade-off between speed and sustainability of electrification efforts needs to be carefully managed.
- Technical standards appropriate for rural areas should be developed and enforced right from the start of the national electrification program.
- Electrification goals should not happen at the expense of the national utility's financial viability.

Source: SEAR Case Study: Vietnam's national electrification program, forthcoming.

FIGURE O.5 Electrification Becomes a National Priority
(Vietnam Household Electrification Rate, %)

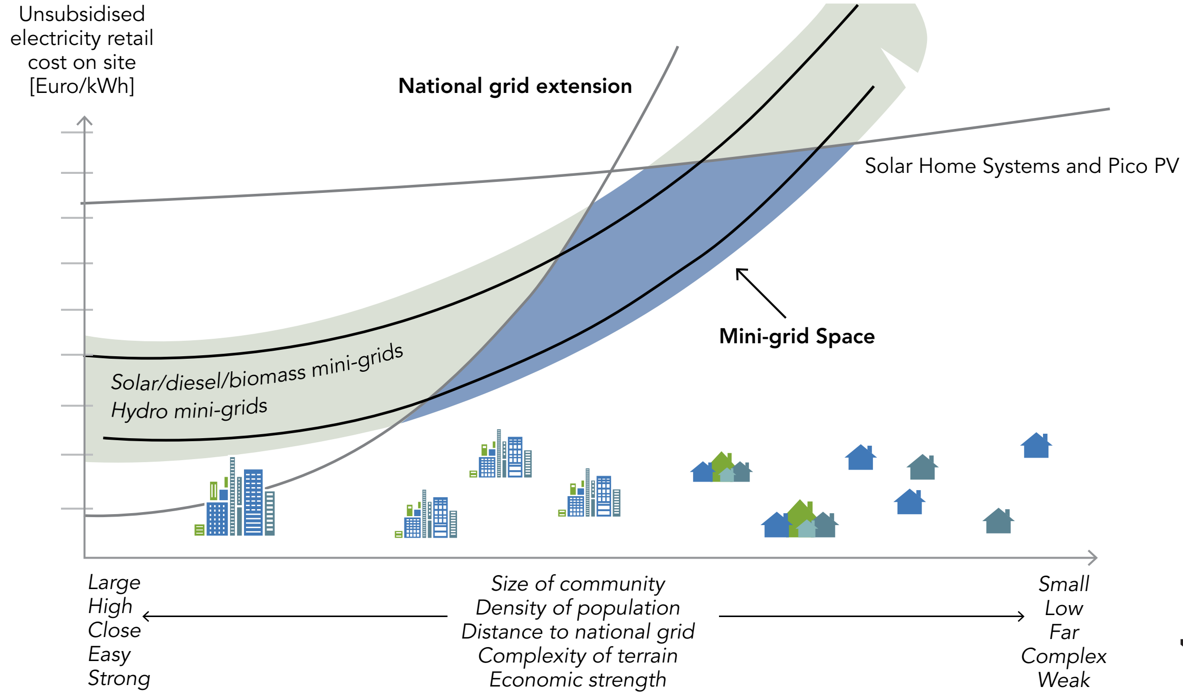


Further, with the rapidly decreasing costs of stand-alone/isolated renewable energy systems, renewable energy is no longer an expensive solution for electricity access. Solar lanterns, solar mobile phone chargers, and certain solar home systems can provide Tier 1–3 energy services (as per the Global Tracking Framework Tier Based System) for between 4 and 20 percent of the cost required for grid extension. Solar Aid, a private solar company, which has sold some 1.5 million solar lights (benefiting some 9 million people), estimates that $10 solar lights can help African families save an average of $60 annually, simply by not using kerosene for lighting purposes.

The stand-alone electricity product market is expanding rapidly, and Navigant Research estimates the market for pico-solar products will grow from $550 million in 2014 to $2.4 billion in 2024. Globally, some 20 million households are now powered by solar home systems and 0.8 million households are supplied by small scale wind systems, according to IRENA estimates. Pico solar PV systems—which typically provide less than 10 watts of power and are primarily used for lighting or powering electrical appliances (like radios or mobile phones)—have developed rapidly in recent years, due to the fall in price of solar modules, the use of highly efficient LED

FIGURE O.6 A growing role for mini grids and renewables

(Opportunities for grid extension, mini grids, and distributed renewable energy systems)



Source: EUEI PDF/REN21 2014.

lighting systems, and the emergence of innovative business models.

So what are the biggest obstacles that countries face in introducing and scaling up the share of renewables in energy use? They range from the presence of large fossil fuel subsidies, the inadequate communication of the advantages of renewables, unclear government policies, a lack of good financial options, and insufficient community involvement. Fortunately, these obstacles can be ameliorated by the creation of a pro-renewables policy and long-term government commitment—sand within this framework, innovative business models are emerging and are leading off-grid electricity access developments.

Energy efficiency, once overlooked, is being seen increasingly as a tool in delivering modern and clean energy services. It reduces the costs of energy supply, therefore making access more affordable. For example, energy efficient light emitting diodes (LEDs) radically reduce the size and costs of the solar PV and batteries needed to provide service, making these technologies affordable for vast new market segments. By end-2015, at least 146 countries had enacted energy efficiency policies, while at least 128 countries had energy efficiency targets. There has also been a drop of more than 30 percent in the primary energy intensity between 1990 and 2014.

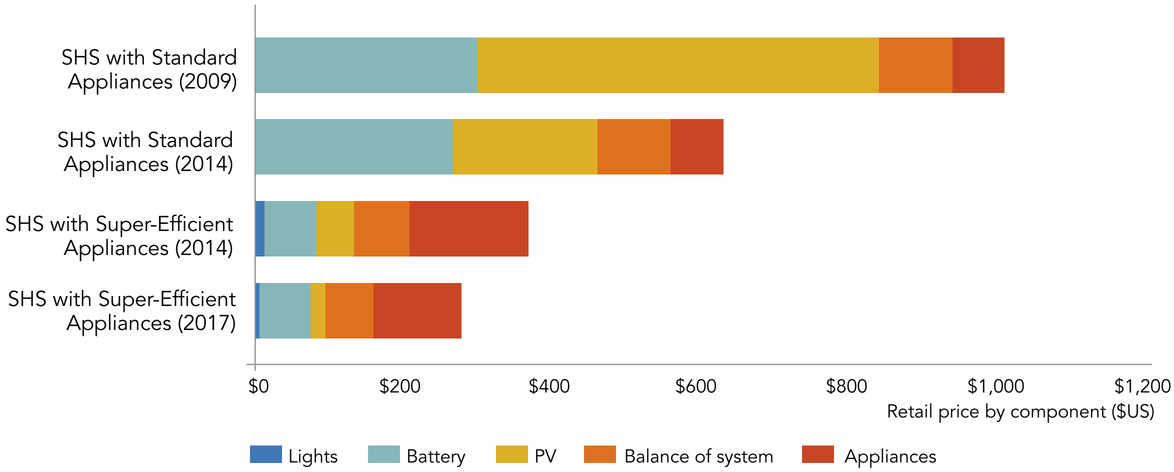
What is hindering energy efficiency from playing a bigger role? The barriers are many: (i) high tariffs and import duties on appliances and equipment used in those markets where access is to be increased; (ii) financial constraints that tend to favor products with the lowest initial cost, even though many products with superior energy performance have a lower lifecycle cost despite a higher upfront cost; (iii) a lack of overlap between professional communities engaged on electricity access and on energy efficiency; and (iv) a lack of focus on the overall energy sector, often because of concentration on solutions involving increased grid generation capacity.

Even so, there are many examples of smart practices and effective models for incorporating energy efficiency. Some high-impact programs have prioritized a broader view on developing electricity access markets looking to commercial and supply-chain management, policy reform, and consumer awareness. One relatively simple way to improve efficiency is through distribution transformers, which are an integral part of every grid. Transformers are a globally traded product, and at least 16 developed and developing economies (including Brazil, China, India, Mexico, and Vietnam) have either minimum energy performance standards or labels in place that regulate or facilitate the installation of highly-efficient transformers. These existing efforts make the establishment of new programs and policies far less burdensome for developing economies.

The success of off-grid technologies for providing energy solutions in recent years is largely attributable to the availability of energy efficient appliances. For instance,

FIGURE O.7 Solar home systems are increasingly offering more for less

(Retail purchase price for three solar home systems that provide identical levels of service)



Source: Phadke, A. et al. 2015.

in many countries the use of high efficient LED lamps has enabled the implementation of various modern lighting programs and initiatives in rural and electrified areas. As the Royal Swedish Academy of Sciences put it when announcing the 2014 Nobel Prize in Physics: "The LED lamp holds great promise for increasing the quality of life for over 1.5 billion people around the world who lack access to electricity grids. Due to low power requirements, it can be powered by cheap local solar power."

Energy efficient appliances have helped to reduce the energy investment costs required to kick-start electricity access programs. Shaving a single watt from an off-grid appliance's load results in lower initial solar package costs, improved service, or both (Van Buskirk 2015). Similarly, energy efficiency can make larger off-grid solar home systems more affordable. According to a recent analysis "the upfront cost of a typical off-grid energy system can be reduced by as much as 50 percent if super-efficient appliances and right-sized solar PV and batteries are used, while delivering equivalent or greater energy service." (Van Buskirk 2015). Thus, advances in energy-efficient devices now allow households to reap more benefits from the relatively small amounts of electricity available to them. Instead of illuminating a single light bulb, CFLS and LED lamps use provide more and better light and consumer less energy, leaving enough energy to power other electronic devices such as fans and low-wattage TVs and appliances (Figure O.7).

In sum, it is clear that clean energy will play a strong role in ensuring universal access to energy services. Plummeting costs for renewable energy technologies and adequate energy efficiency measures offer a tremendous opportunity for countries to think differently and be creative about electricity access expansion.

WHAT ARE THE EMERGING AND INNOVATIVE BUSINESS AND DELIVERY MODELS?

A major focus of the universal electricity access push these days is reaching people living in remote areas, but it is increasingly clear that the traditional approach to electricity grid extension will not suffice. Grid-based extension of electricity supply involves significant upfront investment by utilities, and the connection costs to remote areas—which demand less electricity—are high. Consumers cannot afford large upfront costs, so payback to the utilities can be achieved only over an extended period, or is simply not feasible. Until recently, support for non-grid electricity systems has been based on funding allocations from public programs, but this approach is not sustainable.

There are good prospects for private sector business applications to supply this market, but there are only a limited number of successful installations. Experience from such approaches to energy service delivery suggest that the best models have a number of common features (Table O.1): (i) consideration of the demands, interest, and restrictions of local customers, including the desire to pay with mobile payments systems; (ii) strong partnerships along the whole supply chain, from the government and utilities to private sector service providers; and (iii) adaptation of market dynamics to local conditions to support successful, sustainable clean energy solutions.

In Tanzania, E.ON has five small-scale rural electrification systems operating, with connections to 200–300 customers. The overall goal is to electrify 1 million people in 10 years, or about 250,000 households—which means that between now and entering the scale-up phase, it must develop the ability to standardize. In Nepal, Gham Power, a developer of solar micro-grids and commercial off-grid systems, has deployed over 600 projects, including large industries, small businesses, and hundreds of households.

These applications include three micro grids, with the intention to develop at least 100 such projects in the next few years. The three existing projects have been implemented in partnership with N-cell, the largest telecom company in Nepal, which participates both as an investor and as an off-taker (with a PPA) from the micro-grid system.

Pay as you go (PAYG) models have become increasingly attractive in many markets. This is based upon experience suggesting that, even under local conditions in remote markets, the key to a cost-effective stand-alone energy system business is a finance model that matches affordable pricing for the target consumers with an adequate return on investment for the supplier. PAYG solar companies seek to provide energy services at a price point that is less than, or equal to, consumers' current spending on kerosene, candles, batteries, and other low-quality energy services. Providers are incentivized to offer quality after sales service, since a user's ongoing payments are tied to the system continuing to function.

PAYG providers can take one of two approaches to financing the system to the consumer:

- An indefinite fee for service in which the consumer never owns the system itself, but rather merely pays for the ability to use it. Payments are typically made on the basis of when the consumer needs power and can afford it.
- The consumer eventually owns the system after paying off the principal of the system cost—and the consumer must make discrete payments, typically on a daily, weekly, or monthly basis (thereby resembling a typical financing arrangement).

Lighting Global (a World Bank platform) has estimated that there are 32 PAYG companies in 30 countries, many of them in Africa. They use existing mobile payment systems or scratch cards for fee collection. Consumers benefit from increased affordability, increased confidence in the prod-

TABLE O.1 An array of emerging delivery models for mini-grids

COMPANY	OUTREACH	CURRENT TARGET	COUNTRIES	ENERGY SOURCE	SIZE RANGE	FOCUS/INNOVATION
E.ON	7 systems, 420 customers	1m people in 10 years	Tanzania	Solar, bio-diesel	6–12kW	Standardisation for scale; Establish track record for finance Cellphone payment
GHAM POWER	3 micro-grids	>100 micro-grids in 10 years	Nepal	Solar	1–10kW	PPA with N-cell (telecoms) for reduced risk revenue stream Rent-to-own agreements
HUSK POWER	15,000 house-holds, several 100 businesses	75,000 house-holds, 10,000 businesses, 125 agro units	India Tanzania	Biomass, Solar	15–250kW (biomass); 20kW (solar)	Accept >5 year payback Targeting 8–10 year loans Rural empowerment 3-year expansion plan Inclusive business model
INENSUS	Supports mini-grid development in Africa with related management systems and consultancy		Senegal	Solar, Wind	5–10kW	Low-cost smartcard meter Sale of "electricity blocks" "MicroPowerEconomy" delivery system—flexible tariffs & micro-credit
M-KOPA	340,000 homes (Mar 16)	+500 homes/ day	Kenya, Tanzania, Uganda,	Solar	5–20W	PAYG business model Small SHS, LEDs & mobile phone charging services
POWERGEN (RENEWABLE ENERGY)	20+ mini-grids	50 mini-grids in 2016	Kenya & Tanzania, Zambia	Solar	1–6kW	Mini-grids compatible with central grid standards
POWERHIVE	4 sites, 1500 people (~300 connections)	100 villages	Kenya, Philippines (Africa/Asia expansion)	Solar	~20kW	Integrated tech system; Mobile money networks for pre-payment Dedicated software—predict revenue streams;
RUAHA POWER	1 pilot project (JV with Husk Power)	100 projects	Tanzania	Solar, biomass	300kW	Business model without subsidies Build Own Operate model Pre-payment meters
SPARKMETER	3 Earthspark mini-grids in Haiti	No fixed target	Asia, Africa, Latin America	Service for all types of mini-grids	0–500W	Metering with mobile payment system Cloud-based software "Gateway" usage dbase

uct, and access to maintenance services. For the supplier, PAYG lowers the transaction costs without the need for a significant rural financial infrastructure, and it reduces the cost and risk of doing business. M-KOPA Solar is an often-cited example of a firm with good experience of successful PAYG applications, having connected more than 330,000 homes in Kenya, Tanzania, and Uganda to solar power with over 500 new homes being added every day (Economist 2016).

Increasingly, operators in the off-grid market are dealing strategically with a set of factors that are opening space for business—notably, (i) thinking broader than energy; (ii) seeking a mix of public and private finance; (iii) combining investment with assistance; (iv) dealing with affordability issues in context; (v) engaging with consumers; and (vi) providing after-sales service.

The key challenge centers on the need for accessible financing models—which are starting to be launched in the form of new finance and investment companies that focus on mini-grids and solar home systems (SHSs). These firms, all established within the past few years, provide several means of financial support, including early-stage corporate investment, working capital, asset management, portfolio aggregation, and securitization. One way to offset the investment risk that arises in this sector has been to allocate short-term public funding. This allows project developers to offset upfront development costs. Recognizing the need for such early-stage support, a range of international development organizations is active in facilitating the establishment of new delivery models. However, such subsidies are difficult to access and other frameworks are being proposed that could be more effective, including performance based subsidies, and risk-adjusted subsidies for capital and operating expenditures.

In sum, emerging and innovative energy service delivery mechanisms are encouraging. Innovations in technologies and business models particularly present unprecedented new opportunities for private sector-driven off-grid electrification. If countries create the necessary environment for them to be replicated and scaled up, they could accelerate efforts to achieve universal access to modern energy services.

MOVING FORWARD

In developing countries, traditional grid supply will be the predominant approach for supplying urban households, whose number is likely to rise faster than population growth because of large rural-urban migration and the downward trend in household size. However, this approach will not be sufficient for meeting the goal of universal access to modern energy services by 2030. Developing countries will also need to use mini-grids and off-grid supply to provide access to the more remote households, whose global population is predicted to remain roughly constant during this period.

Mini-grids and off-grid solutions to energy supply are experiencing rapid falls in cost, because of technology improvements and scale economies in supplying growing markets. Even at the lower hydrocarbon prices of recent years, solar- and wind-based generation supply solutions are approaching parity with traditional hydrocarbon-based generation. The very high on-grid distribution costs associated with connecting remote households in areas of low population density will mean that few of these households will be able to afford grid-connection—unless there are subsidies available to cover a large fraction of these costs. Even schemes of spreading repayment of such charges over several years are unlikely to be financially viable without subsidies.

However, even with a cost superiority to on-grid supply, mini-grid and off-grid electricity will require state support through a number of channels: (i) a long-term commitment by the government to the goal of reaching universal access; (ii) the creation of institutions and regulations to facilitate the expansion of new forms of energy supply; and (iii) where needed, some financial support either to households so that they can afford access, or to firms to reduce the high initial costs of developing a new business model to deliver energy to previously unserved customers.

The bottom line is that substantial progress toward meeting the 2030 universal access to modern energy services goal can be expected in the coming years with the large number of different approaches that are now under way to supply off-grid electricity to supplement efforts in grid electricity expansion. But this will only occur if countries succeed in creating the enabling environment to de-risk and to attract the much-needed private sector investments.

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CHAPTER 1

THE CASE FOR UNIVERSAL ELECTRICITY ACCESS

KEY MESSAGES

- Universal access to modern energy services is a necessary enabler to achieve the 2030 Agenda for Sustainable Development. It should be dealt with as a matter of urgency to increase the likelihood of achieving the Sustainable Development Goals (SDGs).
- Access to electricity is essential to break the vicious circle of poverty and to ensure acceptable basic living standards of populations. It plays a catalytic role in addressing the challenges of job creation, human development, gender equality, security, and shared prosperity.
- Without access to affordable and reliable energy services there are limited prospects for the cost-effective delivery of goods and services and therefore few opportunities to develop productive activities needed for the social and economic transformation of rural communities.
- Thus, planning for universal access to modern energy services should be an integral part of national planning efforts to achieve the SDGs.
- Dealing with the challenge of universal electricity access in a context of increasing awareness of climate change impacts offers an opportunity for countries to explore innovative pathways to develop sustainable and resilient communities.

INTRODUCTION

Why is electricity access critical for the achievement of the 2030 Agenda for Sustainable Development? Certainly, there is a broad consensus that access to modern energy services is an essential—although not sufficient—pre-requisite for alleviating poverty. Without energy, it is challenging, if not impossible, to promote economic growth, overcome poverty, expand employment opportunities, and support human development. Nonetheless it is important to integrate electricity access efforts within other sector-specific policies in order to leverage the inter-dependence of different types of infrastructure and maximize impact through synergies.

The objective of this chapter is to demonstrate why energy is important for sustainable development, and how ensuring universal access to affordable and reliable modern energy services can contribute to reducing poverty, promoting human development, and increasing economic growth. The chapter starts by showing how energy can contribute to achieving the Sustainable Development Goals (SDGs). It then discusses how electricity is related to economic growth and explores the impacts of energy on poverty reduction. Next it examines how electricity access can affect human development –particularly health, education, employment, and women's empowerment—before concluding with a discussion of the carbon footprint of achieving universal electricity access.

The chapter finds that planning for universal access should be an integral part of national planning efforts to achieve the SDGs. Moreover, dealing with the challenge of universal electricity access in a context of increasing awareness of climate change impacts offers an opportunity for countries to explore innovative pathways to develop sustainable and resilient communities.

ENERGY IS NECESSARY TO ACHIEVE SUSTAINABLE DEVELOPMENT GOALS

The development community recognizes energy as catalytic in achieving the 2030 Agenda for sustainable development. Energy is a key factor for sustainable development and poverty alleviation, and it plays a central role in every major challenge and opportunity that the world faces. Sustainable energy is now the seventh goal of the 17 Sustainable Development Goals (SDGs) and aims to "ensure

BOX 1.1

Sustainable Development Goal 7 Targets

- By 2030, ensure universal access to affordable, reliable and modern energy services
- By 2030, increase substantially the share of renewable energy in the global energy mix
- By 2030, double the global rate of improvement in energy efficiency
- By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, Small Island Developing States, and land-locked developing countries, in accordance with their respective programs of support

Source: UN 2016.

access to affordable, reliable, sustainable and modern energy for all", including 5 targets (Box 1.1). With energy among the SDGs, a series of opportunities are expected to emerge in terms of financial resources as well as technical assistance, to help countries reach energy-related goals and targets.

For example, electricity and water resources are inextricably linked. As indicated by the SEAR Special Feature Paper on Energy Access and the Water-Energy Nexus (Rodriguez et al 2017), significant amounts of water are needed in almost all energy generation processes, including electricity generation and fossil fuel extraction and processing. Conversely, the water sector needs energy to extract, treat, and transport water. Energy and water are also both required to produce crops, including those used to generate energy through biofu¬els. Furthermore, Rodriguez et al (2017) noted that the energy poor and water poor are often the same people. But for universal access to an improved water source to occur, there needs to be integrated energy and water planning.

HOW IS ELECTRICITY RELATED TO ECONOMIC GROWTH?

Electricity affects economic output by virtue of being part of the production function, along with labor and capital (Stern 2011). It is required to both power industrial processes and to produce goods, equipment, and services in the majority of productive sectors within an economy. The use of modern forms of energy can (i) underpin the creation and upgrading of value chains; (ii) facilitate the diversification of economic structures and livelihoods; and (iii) reduce vulnerability to multiple stresses and external shocks (EUEI 2011). But although energy is a necessary factor, it is rarely sufficient, as access to finance, markets, raw materials, technology, and a qualified workforce is also necessary for driving economic growth.

There is an extensive literature showing a strong correlation between electricity consumption and GDP growth, but it remains inconclusive as to the existence and the direction of causality. The electricity and economic growth nexus has been studied extensively, but empirical evidence shows conflicting results regarding the relationship between the two variables, based on four different hypotheses (Box 1.2). Despite the wide range of estimates in the literature, there is no prevailing hypothesis explaining the link between energy consumption and GDP growth (ECA 2014; CDC 2016). Moreover, studies typically ignore key variables of the production function (such as labor and capital or electricity prices), leading to a possible misidentification of the causal pattern, and thus cannot provide a reliable assessment of the link between energy use and GDP (Bacon and Kojima 2016).

Power shortages are estimated to have a significant impact on economic growth and productivity. It is widely accepted that outages adversely impact economic activities. Several approaches are being used in the literature to estimate the effects of power shortages on the economy, in order to explain the benefits from projects that reduce power shortages—such as more generation or transmission capacity, pricing schemes to reduce peak loads, or other investment upgrades that improve the quality of power supply (Bacon and Kojima 2016).

- In Sub-Saharan Africa, the cumulative time of electrical supply interruptions amounts to about three months of production time lost per year, and as a result, businesses loose about 6 percent of their turnover, while about half of them are using generators, bearing higher costs (Karekezi et al. 2012).
- In Tanzania, the World Bank Enterprise Surveys showed that power outages in Tanzania in 2013 cost businesses about 15 percent of annual sales (CDC 2016).
- At the macroeconomic level, the proportion of GDP lost to unreliable electricity supply can reach close to 7 percent in some countries in sub-Saharan Africa (Foster and Briceno-Garmendia 2010).

TABLE 1.1 Sustainable Development Goals and key links to energy

SUSTAINABLE DEVELOPMENT GOAL	HOW ENERGY IS RELATED TO THE SUSTAINABLE DEVELOPMENT GOALS
GOAL 1. End poverty in all its forms everywhere	Access to energy can increase household income and productivity and reduce disparities in wealth.
GOAL 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	The availability of energy is a key factor for increasing agricultural productivity and ending extreme hunger.
GOAL 3. Ensure healthy lives and promote well-being for all at all ages	Energy access for healthcare services can enhance maternal health, reduce infant mortality, and help curtail disease and epidemics.
GOAL 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Energy is a key factor of upgrading educational facilities and of facilitating modern quality education.
GOAL 5. Achieve gender equality and empower all women and girls	Better access to energy can lead to higher gender equality, freeing up women's time (previously wasted in collecting fuelwood for example) and providing income-generating opportunities.
GOAL 6. Ensure availability and sustainable management of water and sanitation for all	In the energy sector, water is used for generating hydropower, cooling thermal power plants, extracting, processing and transporting energy resources, and growing energy crops. Conversely the water sector needs energy to extract, treat and transport water, as well as for irrigation and desalination.
GOAL 7. Ensure Access to affordable, reliable, sustainable and modern energy for all	
GOAL 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	The provision of energy helps to increase GDP and productivity. Modern energy access empowers people.
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Energy is needed for developing infrastructure and technological innovation, including information and communication technologies (ICT).
GOAL 10. Reduce inequality within and among countries	Access to energy is crucial for sustained income growth of the bottom 40 per cent.
GOAL 11. Make cities and human settlements inclusive, safe, resilient and sustainable.	Energy facilitates all urban systems, including transport and is needed for improving living standards in urban slums.
GOAL 12. Ensure sustainable consumption and production patterns (SCP)	Sustainable energy consumption & production is a key factor in sustainable consumption and production patterns including addressing inefficient fossil-fuel subsidies and removing market distortions.
GOAL 13. Take urgent action to combat climate change and its impacts	Emissions from the energy sector are the leading contributor to anthropogenic climate change. Access to renewable energy and energy efficiency are key to mitigation.
GOAL 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Tidal energy and ocean wind power are important renewable energy technologies but may impact marine ecosystems.
GOAL 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	The environmental impacts of energy encompass deforestation, mineral extraction and changes in land use, and this can lead to desertification and land degradation. Sustainable use of energy resources is key to sustainable terrestrial ecosystems.
GOAL 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Access to fossil fuel resources has historically been a cause for conflict and global price volatility that leads to international instability among and within countries.
GOAL 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Strengthening the means of implementation involves transfer of energy technologies and capacity building for implementing SDG targets and indicators nationally.

BOX 1.2

Energy Consumption and Economic Growth Hypotheses

GROWTH HYPOTHESIS: There is a unidirectional causal link from energy consumption to economic growth. An increase in energy consumption will have a positive impact on economic growth, while limited access to modern energy can limit economic growth.

CONSERVATION HYPOTHESIS: There is a unidirectional causal link from economic growth to energy consumption. Economic growth will lead to increased energy consumption, while energy conservation policies (such as energy efficiency and demand management) will not adversely impact GDP growth.

FEEDBACK HYPOTHESIS: There are bidirectional causal links between energy consumption and economic growth. Changes in energy consumption will have an effect on economic growth whilst changes in economic growth will impact the demand for energy.

NEUTRALITY HYPOTHESIS: There is no causal link between energy consumption and economic growth. An increase or decrease in energy use will not affect economic growth and vice-versa.

Source: CDC 2016.

Studies investigating the effects of increased energy infrastructure on GDP, show that the size of the power sector determines the growth and level of GDP, while increases in the quantity and quality of infrastructure were associated with a reduction in inequality. There is a general consensus that infrastructure is a key contributor to economic growth . Calderón and Servén (2010) analyzed the effects of infrastructure (including power, telecommunications and roads) on GDP growth, and on income inequality. Results showed that annual world growth rose by 1.6 percentage points due to infrastructure increase—of which 1.1 percentage points were due to the accumulation of infrastructure stocks and 0.5 percentage points to the increase in quality. The largest contribution was made by South Asia. On the other hand, Sub-Saharan Africa experienced an increase of 0.7 percentage points, of which 1.2 percentage points were due to increasing quantity, while falling quality was responsible for a 0.5 percentage points reduction. The increase in infrastructure development globally was related to a decline of 3 percentage points in the Gini coefficient, of which 2 percentage points were due to quantity and 1 percentage point was due to quality.

The existence of complementarities between different types of infrastructure leads to higher level of economic output. Infrastructure should be examined as a whole in order to capture the existence of complementarities. For example, the benefits resulting from electricity access in a hospital would be greatly increased if such access is coupled with availability of paved roads allowing patients to reach the hospital, availability of clean water and telecommunication. Because of such complementarities, the link between provision of reliable infrastructure and economic output can be more easily demonstrated (Bacon and Kojima 2016).

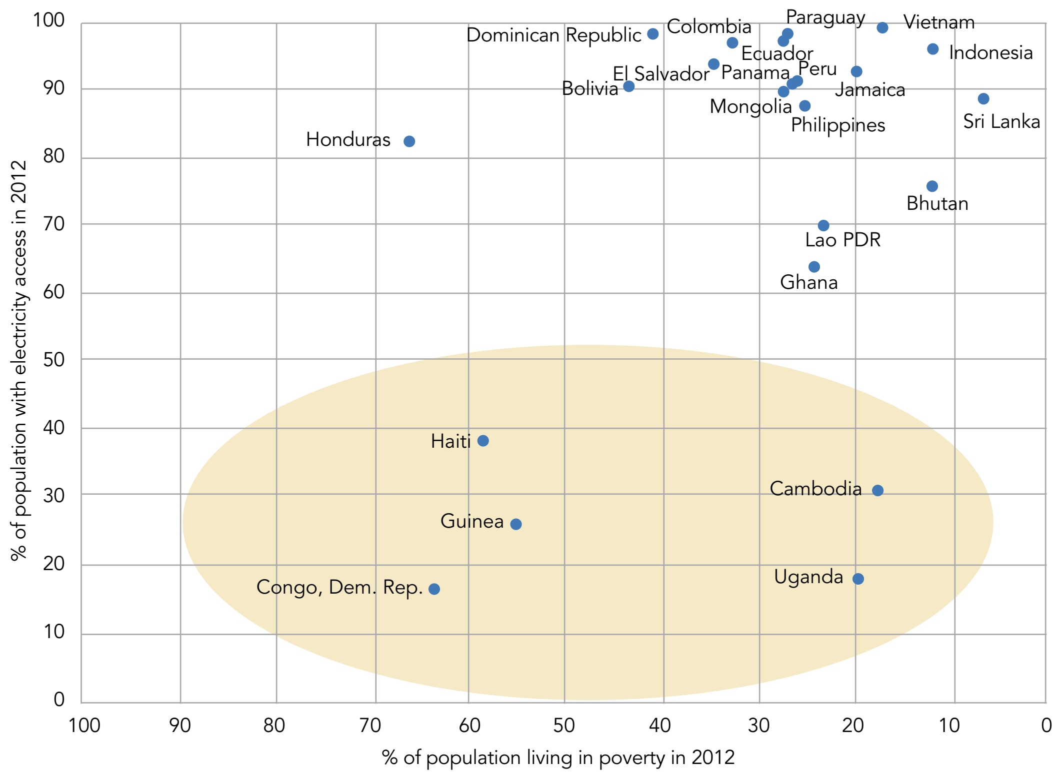
RELIABLE AND AFFORDABLE ENERGY SERVICES CAN CONTRIBUTE TO POVERTY REDUCTION

Lack of access to modern energy services is correlated to higher levels of poverty. Countries with the highest levels of poverty also tend to have lower access to modern energy services. This is most pronounced in Sub-Saharan Africa and South Asia, where a large share of the population depends on traditional biomass for cooking and heating and lacks access to electricity (Figure 1.1).

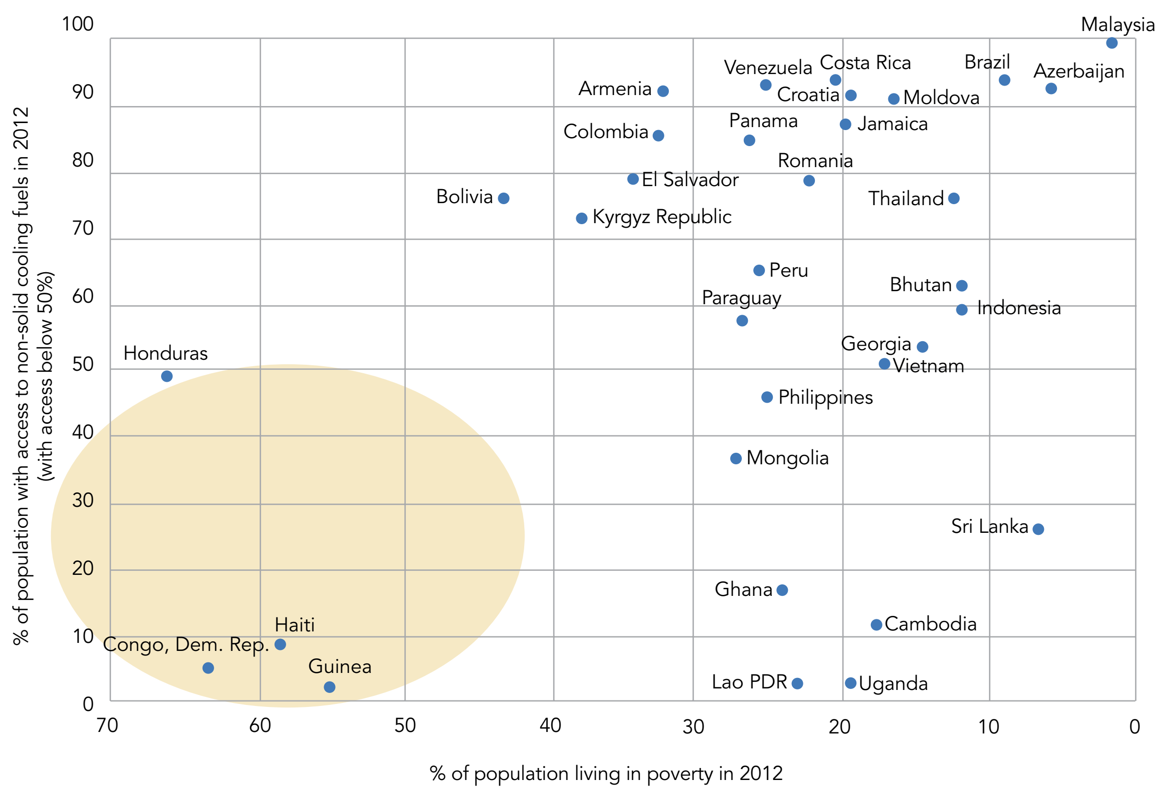
There is a two-way causal relationship between the lack of access to modern energy services and poverty, also called the vicious cycle of energy poverty. People who lack access to reliable and affordable modern energy services are often trapped in a re-enforcing cycle of deprivation and lower income. Economic productivity (particularly in the agricultural sector), opportunities for income generation, and the ability to raise living standards are strongly affected by the lack of modern energy. Malnourishment and low earnings contribute to the poor remaining poor, and perpetuating the lack of access to modern energy (Karekezi et al. 2012). In addition, the poor use significant amounts of their limited income on expensive and unhealthy energy forms that provide weak or unsafe services. Plus, low-income households spend a much larger share of their income to cover basic energy needs than higher income groups (Hussain 2011; Masud 2007). Plus, the poor pay on average higher unit prices for energy services (such as lighting, phone charging, heating, and cooking), as they often use poorly efficient fuels (like kerosene for lighting) or expensive electricity (like battery-based electricity or diesel generators), due to non-availability of grid-based energy sources (like electricity and natural gas) or unaffordable connection cost and related appliances. Finally, poor households tend to pay higher prices due to poorly efficient appliances, or poorly insulated houses for heating services.

FIGURE 1.1 Africa and South Asia are the hardest hit

Panel a: Access to electricity and poverty levels (Countries with access <99%)



Panel b: Access to non-solid cooking fuels[1] and poverty levels (Countries with access < 50%)



[1] Only primary cooking fuel is considered.

Source: GTF 2015; World Development Indicators—Poverty headcount ratio at national poverty lines (% of population):

Fortunately, this vicious cycle can be reversed once the poor are able to switch to reliable and affordable modern energy services. Access to modern energy services contributes to creating employment, increasing trade, and supporting value-adding activities—facilitating the accumulation of "surpluses" or savings that will enhance nutrition and health, improve housing conditions, and facilitate access to education, thus contributing to overcoming poverty (Karekezi et al. 2012).

Several studies estimating the benefits of electrification on households or small businesses suggest that electrification results in an increase in household income, but the magnitude varies considerably from country to country. Access to modern energy services results in a wide range of benefits for households and small businesses (Khandker et al. 2013). Several studies have estimated the effects of electrification on household income—or expenditure. In Bhutan, one study reported that farm income was unaffected while non-farm income increased by 63 percent (Kumar and Rauniyar, 2011) In India, a study found that non-farm income rose by 28 percent (Khandker et al. 2012), while in Vietnam, a study showed an increase of 23 percent in total income (Khandker et al. 2013). Consumption levels also increased significantly in some studies. Interestingly, unconnected households in villages where there is access to grid electricity exhibited higher consumption, although to a much smaller extent (1 percent) (van de Walle et al. 2013).

However, recent studies show that the benefits of electrification can be overestimated if the endogeneity of the electrification status of a household is ignored. The electrification status of a household may be endogenous—that is, electrification does not only affect income but income can also determine whether or not a household is electrified. Higher-income households are more willing to get a connection as soon as the grid arrives (particularly if the connection fees are not fully subsidized), but also utilities prefer to provide electricity to higher-income communities. These effects lead to an overestimation of the effects of electrification on income, as demonstrated by alternative estimation methods (such as instrumental variable (IV) estimation, propensity score matching (PSM), and panel data analysis allowing for heterogeneity between households) (Bacon and Kojima 2016).

HUMAN DEVELOPMENT CAN SIGNIFICANTLY BENEFIT FROM ELECTRICITY SERVICES

In terms of human development, there seems to be a positive correlation between well-being and access to modern energy services. Access to modern energy services contributes to human well-being, poverty reduction, and economic growth. Countries with the highest levels of poverty and unemployment also tend to be those with the lowest access to modern energy. There also seems to be a correlation between the level of human well-being (approximated by the Human Development Index [HDI]) and access to energy services (shown by the level of energy use per capita) (Figure 1.2).

Employment opportunities can be enhanced

Similar to the relationship between energy consumption and economic growth, studies show a strong correlation between energy consumption and employment—notably through higher household employment following electrification. However, results differ depending on gender. The majority of the studies show that household employment increases only for women. In Nicaragua, women are 23 percent more likely to work while there is no change for men (Grogan and Sadanad 2013). Similar results can be found in rural Kwazulu-Natal in South Africa (Dinkelman, 2011) and India (Khandker et al. 2012), although one study found the reverse situation for India (Van de Walle et al. 2013). Therefore, further analysis is needed to understand the different results (Bacon and Kojima 2016).

Five theoretical effects can link increased employment and energy consumption:

- *Demographic effect:* A rising population will have a greater demand for energy, while a greater number of workers entering the work force may result in a higher level of energy required.
- *Income effect:* A growing economy that drives higher levels of employment, leads to increased incomes, which results in growing demand for goods and services and thus to higher demand for energy.
- *Price effect:* External price shocks that affect energy sources (such as coal and oil) can have an impact on economic growth and subsequently, on employment.
- *Substitution effect:* Constraints in energy availability can lead to substitution through increased labor and vice-versa.
- *Technological effect:* The replacement of old energy technologies with new ones can enhance employment, the extent of which depends on a country's level of development (CDC 2016).

Energy infrastructure projects are associated with job creation through different channels, including direct, indirect, and induced effects, as well as supply effects. Energy infrastructure investments create jobs through different channels. On one hand, jobs associated with construction, operation, and maintenance of infrastructure assets are created either directly by the developer or indirectly within the supply chain or distribution network that are created as a result of the infrastructure asset (for example, a power plant). Moreover, induced jobs can also emerge through additional rounds of effects (such as spending of workers), resulting in additional employment in other sectors that serve household consumption, thus creating a multiplier for further demand. On the other hand, second-order or growth related jobs can be created throughout the economy as energy constraints to economic growth are removed (IFC 2013). In the case of rural Lao PDR, grid electrification boosted household per capital incomes, household durable assets, and employment of household members (see Box 1.3).

BOX 1.3

Grid Electrification Benefits in Rural Lao PDR

Lao PDR experienced a rapid growth in electricity generation and connectivity over the last three decades. Electric power generation increased from 33MW to 2,000MW between 1975 and 2010, and household grid connectivity grew from 16 percent in 1995 to 46 percent in 2004 and to 77 percent in 2015. However, the transmission network has not been fully developed to provide power to all customers nationwide. As such, investments are required to strengthen the network.

Two of the major donors that are assisting in the energy sector development are the Asian Development Bank (ADB) and the World Bank. The First Power Sector Policy of Lao PDR was formed in 1990 with multiple objectives that included making tariff affordable and promoting economic and social welfare. The Ministry of Energy and Mines has also been deploying its Power to the Poor (P2P) program to bring electricity to the poor, with a gender focus. Data for this study came from a household survey (September 2015-January 2016) by the World Bank's Energy Sector Management Program (ESMAP) in 15 provinces, covering the country's three rural geographic regions. Overall, 3,500 households (1,500 with grid and 2,000 without) were sampled from 200 villages (100 with grid electricity and 100 without). And there was a village survey in each of the survey communities on village infrastructure, development activities, and price alternate fuels.

Key Findings

KEROSENE CONSUMPTION: Kerosene consumption for lighting decreases by 0.33 liter per month as a result of grid connectivity.

ECONOMIC OUTCOMES AND EMPLOYMENT: Grid electrification raises household per capita income by up to 38 percent and per capita expenditure by up to 7 percent. Household durable assets grow by 180 percent because of grid connection. And employment of household members experiences a substantial growth due to grid electrification—up to 53 percent for men and 37 percent for women.

EXPOSURE TO ELECTRONIC MEDIA: Grid electrification increases listening to radio by household members by about 12 minutes per day, and watching of TV by almost 2 hours per day. Grid electrification also increases the use of mobile phone for conducting income-generating activities—by 9.7 percentage points.

WOMEN'S TIME USE: Grid access increases women's time spent in income generating activities by 43 minutes a day. Women in grid households also spend more time in entertainment and leisure than their counterpart women in non-grid households.

EDUCATION: Grid connectivity increases study time in the evening by 30 minutes for boys and 19 minutes for girls. Grade completion by household members also improves as a result of grid electrification. For example, completion of secondary schooling increases by 3.6 percentage points for men and 3.4 percentage points for women because of grid electrification.

In sum, about 25 percent of households in rural Lao PDR do not have a grid connection. So, expanding the grid to non-grid households may spread the benefits, unless geographic conditions are prohibitive. Grid connection has its own problems—namely, outages and blackouts—although these can be resolved by increasing generation capacity, for which donor assistance may be required.

Source: SEAR Impact Evaluation Forthcoming.

Multiple health benefits can be achieved

In terms of health, air pollution is considered the greatest energy-related health risk. Dirty fuels and inefficient technologies generate air pollution. Outdoor (ambient) and indoor (household) air pollution are responsible for about 7 million premature deaths annually, making air pollution one of the largest single causes of premature mortality and morbidity worldwide. Women and children bear the heaviest burden, due to their high exposure (WHO 2014). Studies that examined the global burden of disease caused by air pollution from household solid fuel use for cooking and heating, found that indoor air pollution from solid fuel use accounted for 3.5 million deaths and 111 million disability-adjusted life years (DALYs) in 2010 (Lim et al. 2012), and that the resulting outdoor air pollution caused an estimated 370,000 deaths and 9.9 million DALYs (Chafe et al. 2014).

Fortunately, modern energy services can greatly reduce the burden of diseases associated with indoor air pollution, burns, and poisonings. Sustainable use of clean cooking solutions would reduce the long-term exposure to health-damaging pollutants created by open fires and traditional solid fuel cookstoves. These exposure reductions would decrease the burden from cardiovascular disease (ischaemic heart disease) and respiratory disease (such as childhood pneumonia, chronic obstructive pulmonary disease, or lung cancer), as well as stroke. The risk for burns, scalds, and poisonings would also be reduced. Increasing access to modern heating services and replacing polluting and dangerous kerosene lamps with electric lighting would yield similar results (IEA and World Bank 2015).

Energy also offers multiple health benefits by ensuring clean water provision and improving food quality and nutrition. It can contribute to controlling waterborne diseases (such as diarrhea) through the provision of energy for water pumping, and water treatment and purification. And it can improve food quality and nutrition through cooking and refrigeration (IEA and World Bank 2015). (See SEAR's Special Feature Paper on Modern Energy Access and Health on these linkages; Porcaro et al. 2017).

Further, reliable energy access in health facilities can significantly enhance health care provision:

- Without energy, many life-saving interventions cannot be undertaken, and essential medical devices and appliances for prevention, diagnosis, and treatment cannot be powered.
- Energy can provide lighting, power medical devices, and enable refrigeration for blood and vaccines.
- Electricity access seems to have a notable impact on some key health service indicators, such as prolonging nighttime service provision, attracting and retaining skilled health workers (especially in rural areas), and providing faster emergency response, including for childbirth deliveries. Every day, some 800 women die worldwide from preventable causes related to pregnancy and childbirth (SE4All, 2013).
- Access to electricity in health facilities can increase the number of successful childbirth deliveries, especially at night.
- Electricity access also enables mobile-health applications and facilitates public health education and information.
- Thermal energy is also critical for space and water heating, sterilizing medical equipment, and incinerating medical waste safely (WHO and World Bank 2015).

Education and learning can be improved

Access to modern energy services in the household can translate into increased time for education of rural children. Rural children, especially girls, are often responsible for contributing to household chores, including collection of cooking fuels. One study found a strong association between the time children spends on resource collection and a reduced likelihood of school attendance, especially among girls (Nanhuni and Findes, 2003). Access to modern energy solutions for cooking can reduce fuel collection times significantly, and can translate into increased time for education, encouraging school attendance and reducing dropout rates (Mapako 2010; UNEP 2008). Also, studies report that acute respiratory infections (ARIs), often caused by indoor air pollution, are the principal cause of absenteeism in many developing countries (Gaye 2007). By providing quality lighting for comfortable night-time studying, access to electricity allow children to study longer in the evening (Mapako 2010), which can have a significant impact on learning outcomes, while reducing risks to children's eyesight (WHO 2011).

Access to modern energy services in schools can improve learning and teaching experiences. Energy can contribute to improving basic amenities in schools (such as access to clean water, sanitation, lighting, space heating, and cooling), thus creating a more child and teacher friendly environment, which helps increase school attendance and reduce dropout rates (Bacolod and Tobias 2006). Lighting allows schools to run in the evening to accommodate more and better-sized classes, and facilitates lesson preparation and administrative task for teachers. Students without adequate lighting at home may also stay at school to complete homework. Electricity facilitates access to information and communication technologies (ICTs), improving learning experience through audiovisual teaching aids and equipment (such as projectors, computers, and science equipment). Students can learn computer skills and teachers have more timely access to the latest information. Distance learning and staff training become possible, while administrative tasks are facilitated. Results from the SEAR Impact Evaluation in Laos PDR show that grid electrification increased study time in the evening increases by up to 30 minutes for boys and 19 minutes for girls as shown by Box 1.3 (SEAR Impact Evaluation, Forthcoming). Electrification benefits for educational outcomes are also evident from the solar home system program in rural Bolivia. However, compared grid benefits, SHS benefits seem smaller – SHS adoption in rural Bolivia increases evening study time by up 8 minutes for boys and 6 minutes for girls. Moreover, the increase in study hours does not seem to be enough to influence other intermediate- to long-term educational outcomes (SEAR Impact Evaluation, Forthcoming).

Access to electricity can also increase retention of qualified teachers in rural areas. Rural electrification, particularly grid extensions to rural schools and teachers' residences, tends to have a positive impact on the retention of teachers who are much sought in rural areas. Teachers are more willing to relocate to rural schools when living standards are higher as a result of improved access to electricity (AllAfrica 2004; Cabraal et al. 2005; World Bank 2008; Harsdorff and Peters 2010).

Numerous studies have shown that electrification increases time spent in schooling and on homework. In Bhutan, access to electricity resulted in an increase in the time spent in schooling by 0.54 year and in the time spent on homework by 10 minutes per day (Kumar and Rauniyar 2011). In India, there were significant increases in enrollment (6 percent for boys and 7 percent for girls), study time at home (1.4 hours/week for boys and 1.6 hours/week for girls), and years of education completed (0.3 years for boys and 0.5 years for girls) (Khandker et al. 2012). In Vietnam, there were significant increases in the completion rates for education for boys and girls (Khandker et al. (2013)). There is variation among countries as to the magnitude of these effects and there is no direct evidence within these studies on how increased education leads to increased income (Bacon and Kojima 2016). Anecdotal evidence also supports positive correlation between electricity access and academic success, showing higher completion rates and lower absenteeism in newly electrified schools in Sudan, Tanzania, Kenya and the Philippines (Goodwin 2013; Kirubi et al. 2009; Valerio 2014).

Women's empowerment can be enhanced

In terms of women's empowerment, access to affordable modern energy services can reduce both time and effort spent in reproductive and productive labor. Women are particularly time poor, and the associated drudgery of their tasks (particularly collecting firewood, fetching water, and processing food) is mainly fulfilled through their own physical labor, which has implications for their health and the well-being of their children and families. Studies have shown that women, as well as girls, can have longer working days than men, particularly in rural areas, and carry (usually on their heads) more weight than men (Bardasi and Wodon 2006; Charmes 2006). Women may suffer skeletal damage from carrying heavy loads, such as fuelwood and water (Waris and Antahal 2014; WHO 2004.; Geere et al. 2010), and may also be exposed to sexual and other forms of violence (Kasirye et. al 2009; MSF 2005).

The good news is that empirical evidence suggests that street lighting may reduce the risk of gender-based violence, although social norms and values can take time to adjust after new technologies are brought in (Doleac & Sanders, 2012). By increasing efficiency and productivity, better access improves well-being and frees up time for leisure and rest. Time spent on fetching water can be sharply reduced through piped water supply, often made possible through fuel-based water pumps. The use of modern cooking solutions can decrease time spent in collecting fuelwood, while reducing indoor air pollution. Access to electric labor-saving appliances, such as food processors or washing machines, further improves women's quality of life, and may create income-generating opportunities (IEA and World Bank 2015).

Dissemination of off-grid access solutions can be an opportunity for both men and women, expanding economic activities for women, diversifying productive options, and creating new sources of wealth and income. Besides being energy consumers, women can be important energy providers, expanding electricity access to poor and hard-to-reach customers, individually and through their networks. A growing number of energy enterprises have begun to employ women as sales representatives to reach low-income consumers at the base of the pyramid with lighting and cooking solutions. Women help ensure that energy products reflect the priorities of women users, increasing the likelihood of adoption and continued use (Box 1.4) (CRT/N 2014; Hamakawa & et al. 2014; Johnson 2015; Smith 2015). SEAR's Special Feature on Energy Access and Gender: Getting the Balance Right provides a detailed discussion on energy access and women empowerment (Dutta et al. 2017). Access to modern energy is very important to women. Since women are physically in the home more than men are, they are to benefit more from electricity. Availability of electricity in the household enables women to use labor saving appliances. This may well have an impact on women's time allocation as they give up time-consuming drudgery and are engaged into more productive and satisfying activities. According to SEAR Impact Evaluation findings (see Box 1.3), women in grid connected households in rural Lao PDR spend more time in income generating activities than their counterparts in non-grid households. More specifically, grid access increases women's time spent in income generating activities by 43 minutes a day. Grid access also increases their time spent in entertainment and leisure. SHS adoption also affects same outcomes in rural Bolivia. For example, because of SHS, women spend up to 62 minutes more daily in income generating activities. They also spend more time in satisfying activities such as entertainment (SEAR Impact Evaluation, Forthcoming).

WHAT IS THE CARBON FOOTPRINT OF UNIVERSAL ELECTRICITY ACCESS?

As for the environment, the link between energy and climate change is two-fold, and future impacts are challenging to estimate. The energy system is a major contributor to climate change as it generates greenhouse gas (GHG) emissions through energy production and use, while climate change can disrupt the world's energy system—as extreme weather events, sea level rise, water availability changes, and temperatures increase affect supply and demand of energy. It is particularly challenging to estimate future impacts of the energy sector on climate change, as multiple factors are coming into play.

The future impact of universal access on GHG emissions will depend on the projected level of energy consumption and the expected energy mix of each country. Energy demand is mainly determined by population growth, economic development, and energy efficiency. Different tools and methods of a varying degree of complexity are used to estimate future energy demand (Bazilian et al. 2012), making it challenging to compare results. Nonetheless, as countries make progress toward achieving universal electricity access, the affected populations are expected to gradually come out of poverty—driving higher energy consumption not only in households but also in the industrial and commercial sector. Future CO2 emissions will also depend on the energy mix of each country. The future energy supply system will be affected by regulatory and policy efforts aimed at decarbonizing the economy, with renewable energy and energy efficiency playing a key role. In 2015, the IEA estimated that the world's primary energy demand will increase by 45 percent to 2040 in the Current Policies Scenario, versus a 32 percent increase in the New Policies Scenario and 12 percent in the 450 Scenario—in which 46 percent of primary energy demand is met through low-carbon energy sources (IEA 2015c).

Several studies estimate that achieving universal electricity access by 2030 would only result in a negligible increase of CO2 emissions, as they project that energy demand of the affected population will remain low.

BOX 1.4

Solar Sisters and Solar Grannies—Women in the Solar Energy Sector

In Africa, Solar Sister, a women-led social enterprise founded in 2010, empowers women by recruiting, training and supporting them with a clean energy business opportunity. Solar Sister's last mile distribution network taps into the potential of women's enterprise to eradicate energy poverty in some of the hardest to reach, energy poorest communities. Solar Sister is creating a chain of local, female clean-energy entrepreneurs that sell and deliver world-class solar and clean cookstoves solutions directly to their rural community's doorsteps. In 2016, an independent assessment by International Center for Research on Women (ICRW) found multi-level impacts that extend to Solar Sister entrepreneurs, their families and communities. Entrepreneurs decrease their expenditures on kerosene, mobile charging and fuelwood for cooking, saving on average $200 per year in reduced energy costs. Income from clean energy businesses allows women to contribute to household earnings, gain confidence, financial independence, respect from their families and play a larger role in decision-making power. Over 2,700 Solar Sister entrepreneurs have brought transforming clean energy access to over 700,000 people, and the model is further scaling up.

In India, the Barefoot College in Rajasthan provides training to older women, most of whom are illiterate, to become solar engineers. This focus is a strategic choice, because these women are embedded in their communities, and play a key role in household chores, including energy use. They also are less likely to leave their village to work in the city—which would leave the community without someone to maintain solar panels and lamps—as occurs with the majority of young men. This social justice approach offers the opportunity to older women, one of the most vulnerable social groups, to raise their social status and influence their community, thus defying the perceptions of their obsolescence. Following a six-month course at Barefoot College, Solar Grannies understand how resistors and electrical devises function and can handle controllers and advanced converters. Solar Grannies are able to build solar lanterns, install solar panels and link them to batteries, and carry out repairs.

Solar Sister Business Model: A Complete Value-Chain Innovation.

Source: Solar Sister 2016

- In 2010, the IEA estimated that to achieve universal access to modern energy services by 2030, global electricity generation would be 2.9 percent higher compared to the New Policies Scenario (NPS), while oil demand would rise less than 1 percent. As a result, CO2 emissions would be 0.8 higher compared to the NPS—or around 2 percent of 2010 OECD emissions (IEA 2010). Although the energy mix used in these projections is the one of the 450 scenario, these results are also based on IEA's assumptions about minimum levels of electricity consumption of 250kWh/year for rural households and 500kWh/year for urban households.
- Pachauri et al. (2012) estimate that the climate impacts of achieving universal energy access are negligible or might even be negative, even in the case where access is provided entirely from fossil fuel sources. This would occur because transitioning to modern energy services will displace large quantities of traditional biomass use for cooking and kerosene for lighting, thus improving energy efficiency overall. Nonetheless, the study assumes 420kWh of yearly electricity consumption per household.

- The World Development Report (WDR) 2010 states that "increasing access to electricity services and clean cooking fuels in many low- income developing countries, particularly in South Asia and Sub- Saharan Africa, would add less than 2 percent to global CO2 emissions" by 2050 (World Bank 2010). Such estimates are based on 170kWh of yearly electricity consumption per capita.
- Chakravarty and Tavoni (2013) show that a global energy poverty reduction policy aimed at providing 10GJ of energy per capita per year to the global poor would increase energy demand by 7 percent by 2030, and the impacts on climate change will be very small, even with a carbon-intensive energy infrastructure. Nonetheless, the assumption is that yearly total energy consumption per capita would correspond to 750 kWh and 150 kg of oil, is considered sufficient to ensure productive uses of energy.

However, as people come out of poverty, they will tend to consume higher levels of energy, closer to those of the developed world. As households come out of poverty and enter the middle class, they are likely to purchase for the first time energy-consuming assets, such as vehicles and household appliances (Wolfram et al. 2012). Energy is needed to manufacture and use these new assets, driving energy demand in the industrial and commercial sectors as well. Per-capita energy use differs dramatically across countries with different income levels. In 2010, the average residential yearly consumption of electricity per capita was 2,652 kWh in high-income countries, 378 kWh in middle-income countries, and 179 kWh in low-income countries (World Bank 2013). Assuming that the 1.1 billion people that lack electricity access in 2012, will consume low levels of electricity by 2030, implies that they will remain impoverished (Bazilian and Pielke 2013).

Energy demand forecasts are critical for future planning. Models estimating future energy demand in developing countries should consider the process by which poor consumers move into the middle-class, to be able to quantify the implications of poverty reduction on future energy consumption and related CO2 emissions (Wolfram et al. 2012). Energy forecasts should not understate the degree to which the distribution of economic growth affects energy demand, as they may undermine the achievement of the SDGs. Energy demand forecasts are critical for future planning. In fact, ,underestimating future energy demand is likely to result in a misinterpretation of the scale of the challenge (Bazilian et al. 2012) and lead to inadequate policies and technologies (Bazilian and Pielke 2013; Wolfram et al. 2012).

A joint solution is needed to resolve the energy access and climate change issues. On one hand, there is an immediate requirement to provide reliable and affordable energy to a large population without access, and facilitate economic expansion of emerging economies. But on the other hand, there is a pressing need to limit global warming to an average level of increase of 2°C relative to pre-industrial levels—which implies deep cuts in emissions resulting from energy production and use (as emphasized by the agreement reached in the 21st Conference of the Parties of the UNFCCC in Paris in December 2015).

The challenge is to provide reliable and affordable energy services for economic development without compromising the climate. Low carbon energy options can improve energy security by reducing price volatility or exposure to energy supply disruptions. Such options can also be the least-cost solution for rural electrification in certain areas. However fossil fuels, coal in particular, can provide a low-cost and secure energy source in many cases (World Bank 2010).

It is crucial to include externalities into decision-making process of power system planning. Decision-making processes that focus primarily on expanding energy access but disregarding externalities run the risk of facing higher costs in the future—especially in the case of large, long-lived, and high-emission capital stock (such as coal-fired power plants) (Bazilian et al. 2011). Externalities may be both positive (such as contribution of secure energy supplies to welfare and economic development) and negative (such as CO2 emissions and other adverse environmental impacts). The costs and benefits of these externalities may outweigh the direct costs of building and operating specific energy technologies, but are very difficult to value. Power system planning should use advanced analytical tools to evaluate externalities and show the trade-offs among risks to better inform the decision-making process. (For more, see SEAR's Special Feature Paper on The Climate Change and Energy Access Nexus; Akbar et al. 2017).

CONCLUSION

This chapter has shown that energy is catalytic for achieving the SDGs. It has also shown that ensuring universal access to affordable and reliable modern energy services can contribute to increasing economic growth, reducing poverty, and improving well-being—while promoting human development, supporting health, education, employment, and women's empowerment. For those reasons, it is essential that the international community take steps urgently to make such access happen as quickly as possible throughout the world.

How can this be done? It is critical that planning for universal access be an integral part of national planning efforts to achieve the SDGs. And as much as possible, electricity access interventions should be innovative and designed in a way that they reflect their eventual catalytic nature within context. Moreover, dealing with the challenge of universal electricity access in a context of increasing awareness of climate change impacts offers an opportunity for countries to explore innovative pathways to develop sustainable and resilient communities

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CHAPTER 2

THE STATUS OF ELECTRICITY ACCESS

KEY MESSAGES

- Globally, 1.06 billion people have no electricity—with India and Nigeria having the greatest numbers of people without access to electricity. Lack of electricity access is predominant in rural areas of Sub-Saharan Africa and South Asia, with 20 countries accounting for 80 percent of the global access deficit in 2014.
- Latin America and the Caribbean, East Asia, and South Asia will be able to reach universal access to electricity by 2030—assuming conditions of constant growth in electricity, constant growth in population, and no major changes in political willingness or better access to financial investments.
- However, there would still be several countries—mainly in Sub-Saharan Africa—with a significant percentage of their population without access to modern energy services by 2030 if urgent measures are not taken to reverse course.
- New methodologies to measure electricity access are needed to better spell out exactly where countries stand on the level of energy services to help guide policies and interventions.

INTRODUCTION

What is the status of electricity access? In 2011, the international community launched the Sustainable Energy for All (SE4ALL) initiative, which calls for (i) universal access to modern energy services; (ii) double the global rate of improvement in energy efficiency; and (iii) double the share of renewable energy in the global energy. Yet despite significant progress in recent decades, achieving universal access to modern energy services by 2030 will not be possible without stepped-up efforts.

In 2014, two out of ten people in the world still lacked electricity access (IEA and World Bank 2017). Although the global electricity access deficit has declined since 2000, still 15 percent of the world population do not have electricity. Moreover, these numbers may misrepresent the scale of the challenge, as they reflect a simplistic definition of electricity access that hides several issues—quality, reliability, affordability, and duration.

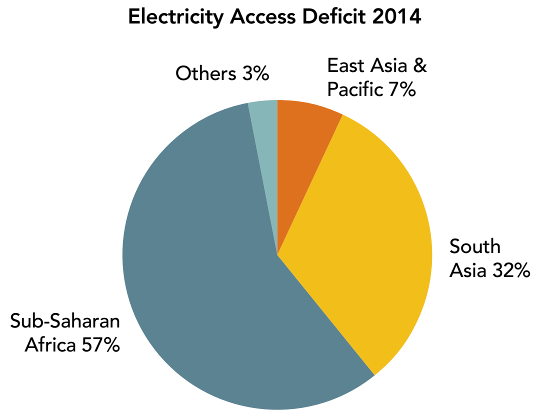
This chapter tries to shed more light on where the global community stands now on universal access to electricity (measured in a binary way—that is, having, or not having, an electricity connection) and what remains to be done to reach the SDG7.1 target: "By 2030, ensure universal access to affordable, reliable and modern energy services." It begins with a snapshot of the status and trends of electricity access, as presented in the Global Tracking Framework (GTF), which identifies indicators for tracking global progress toward the three SE4All objectives (IEA and World Bank 2017). It then explores how four countries (Morocco, Bangladesh, India, and China) have managed to secure huge increases in access between 2000 and 2014. And it finishes with a description of efforts to improve how electricity access is measured—focusing on the Multi-Tier Framework (MTF), which was developed under the umbrella of SE4ALL (World Bank 2017)—which would help policymakers and other stakeholders track their efforts.

SNAPSHOT OF ACCESS TO ELECTRICITY IN 2014

Global Access to Electricity: As of 2014, 1.06 billion people still lived without access to electricity—about three times the population of the United States (Figure 2.1). The electrification rate stands globally at 85 percent, with 96 percent in urban areas and 73 percent in rural areas (IEA and World Bank 2017).

Regional breakdown on access to electricity in 2014: On a regional basis, the electricity access deficit is overwhelmingly concentrated in Sub-Saharan Africa (57 percent of global access deficit—609 million people—six out of ten—do not have access to electricity) and South Asia (32 percent—343 million people do not have access to electricity)

FIGURE 2.1 Africa and South Asia have the largest electricity access deficits



Source: Data from IEA and World Bank 2017.

(Figure 2.1). Electrification rate varies widely across regions: 37.6 percent in Sub-Saharan Africa, 80 percent in South Asia, and near-universal access in all the other regions.

Top 20 access deficit countries: At the country level, India alone has a little less than one-third of the global deficit (270 million), followed by Nigeria (75 million), and Ethiopia (71 million) (Figure 2.2)—and the 20 highest access-deficit countries alone account for 80 percent of the global deficit. The access deficit is overwhelmingly rural, at about 87 percent.

Trends in Access to Electricity

Global Trends: Between 2000 and 2014, there were advances in electrification, with the global electricity deficit declining from 1.3 billion to 1.06 billion. At the same time, the global electrification rate rose from 77.7 percent to 85.5 percent—covering additional 1.4 billion people (Figure 2.3), mostly in urban areas.

Progress with rural electrification is evident since 2000, rising from 63 to 73 percent of the rural population in 2014 adding access to 4oo million people in rural areas. Urban areas across the world are already close to universal access at 97 percent. Although urban access rates have increased relatively little in the last 25 years, this remains a major achievement considering the rapid urbanization that has brought an additional 1.6 billion people into the world's cities during this period (see Box 2.1). Major challenges are in both rural and urban areas.

Regional Trends: Among the regions, improvement in access to electricity in the period 2000–14 has been remarkable in South Asia (rising from 57.2 to 80 percent), South Asia (from 57.2 to 80 percent), and Middle East and North Africa (from 90.9 to 97 percent). Trends in population lacking access to electricity is negative for Sub-Saharan Africa, where 609 million people still do not have access to electricity services. (Figure 2.4)

BEYOND THE NUMBERS

Between 2000 and 2014, Morocco and Bangladesh were among the fastest growers in terms of improving the electrification access rate (Figure 2.5), and India and China were among the countries with the highest number of electrified people per year. Their stories show a variety of approaches (bottom-up versus top-down) and mixes of technologies (on and off-grid).

Morocco Utility-led Rural Electrification Program

In 1990, 49 percent of Morocco's population had access to electricity, but by 2014, that rate was up to 100 percent—the highest increase in the electricity access rate during that period for any country in the world. As a result, 20 million people obtained access, thanks to a utility-led rural electrification program.

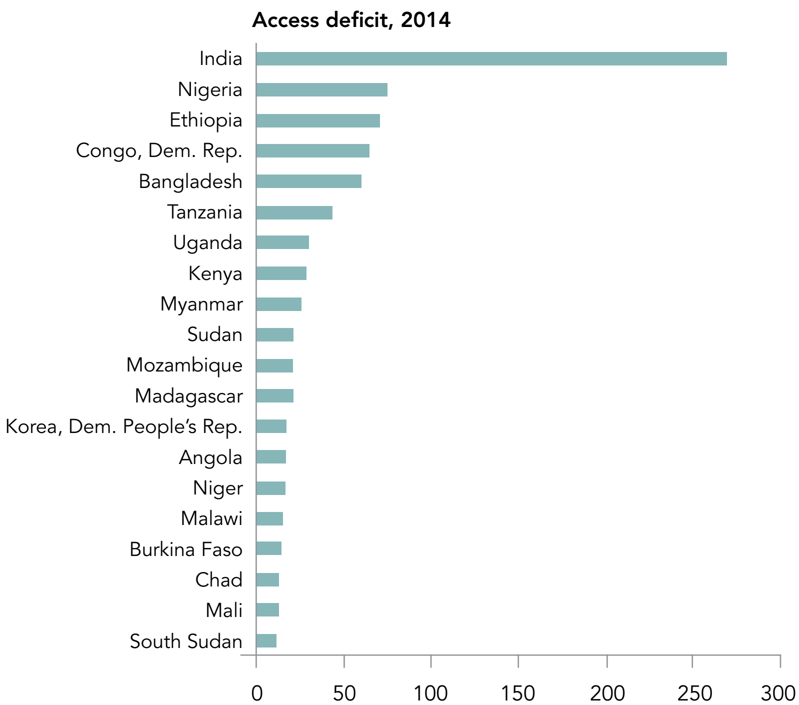
The big push began in 1996, when the government launched the Global Rural Electrification Program (known as PERG), with the national utility (Office National De l'Electricité [ONE]) responsible for implementation. The program was aimed at providing electricity access to all rural households, using least-cost technologies. The ONE prepared a Rural Electrification Master Plan to determine the total investment required to reach 34,000 villages. Data was collected to establish a database of demographic, social, economic, and administrative details for each village, and get a geographical picture of the existing electricity supply networks (George 2002). Although most villages were connected to the central grid, decentralized electrification systems were also installed to help meet local demand at least cost (IsDB 2013). Funding came from local communities (20 percent of the connection cost), beneficiary households (about 25 percent), and the ONE (about 55 percent)—and local communities and beneficiary households were allowed to pay off charges over five to seven years. Pre-paid meters were also provided to help consumers monitor consumption and facilitate payment (IsDB 2013; George 2002).

Three main principles contributed to the rapid rural electrification in Morocco: (i) a clear vision and a continuing political commitment to follow the plan; (ii) an institutional framework leveraging the strength of the utility and including national and international actors; and (iii) a financing model that included all stakeholders, including international financial institutions (Nygaard and Dafrallah 2016). Also important was the high level of urban electrification that allowed cross-subsidization from urban consumers and Morocco's high GDP (compared to Sub-Saharan Africa countries).

Bangladesh Solar Home System Program

Between 2000 and 2014, Bangladesh increased the level of electrical access from 32 percent of the population to 62 percent—an additional 57 million people (IEA and World Bank 2017)—driven by a national off-grid electrification program that provided technical and financing solutions for users (Sadeque et al. 2014). Rural electrification was initially led by cooperatives that managed commercial operation of grid-based electricity supply, financed by the

FIGURE 2.2 India has the world's largest energy deficits
(Top 20 countries for access deficit in electricity, 2014)



Source: IEA and World Bank 2017
Note: These countries account for more than 81 percent of the global access deficit.

FIGURE 2.3: Electrification rising, especially in urban areas
(Trend in population with access for total, urban and rural population 2000–2014)

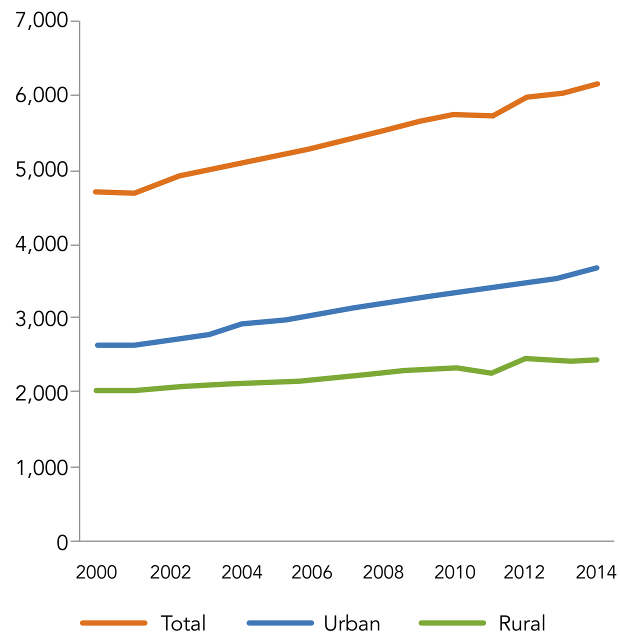
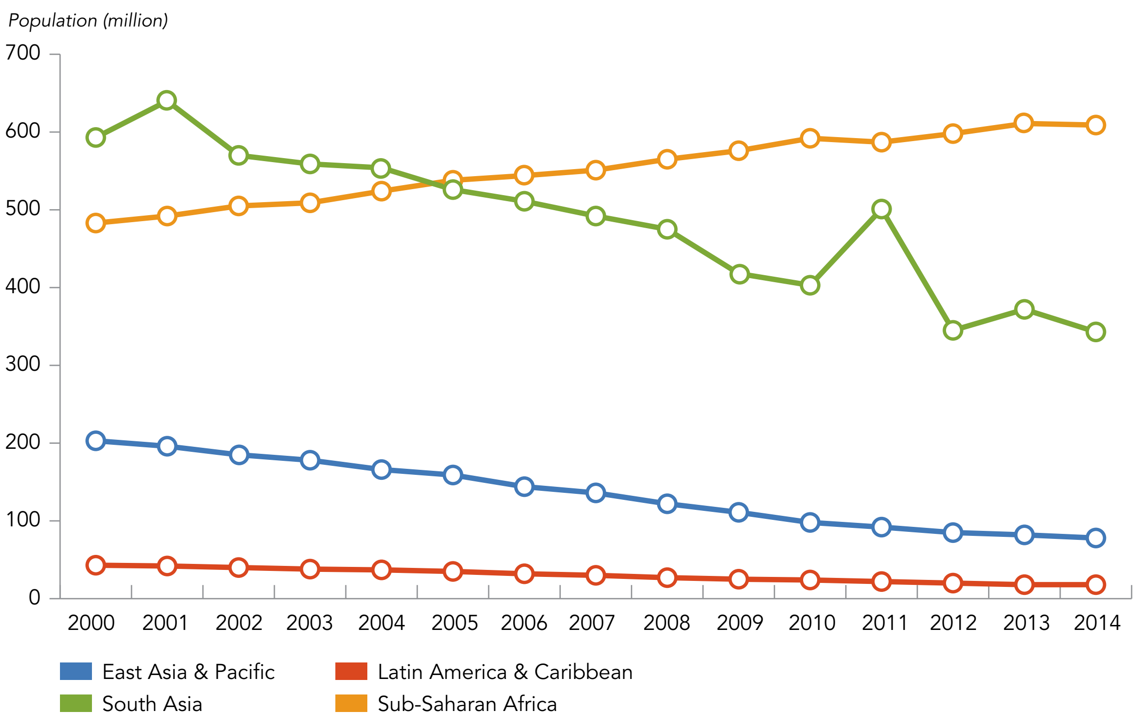


FIGURE 2.4: Sub-Saharan Africa unable to keep up with population growth for electricity access
(Trends in population lacking access to electricity, 2000-2014)



Source: Data from IEA and World Bank 2017

BOX 2.1

Access Challenges in Urban Slums

UN-Habitat estimates that the number of people living in the slums of the world's developing regions stands at 863 million and is expected to increase to 2 billion by 2030 (UN Habitat, 2014). In Sub-Saharan Africa, about 60 percent of the total urban population lives in slums, and in Asia, about 30 percent, with most of the projected increase going to come from Sub Saharan Africa. At the country level, India and Nigeria alone are expected to add 404 million and 212 million people, respectively, to their urban populations, between 2014 and 2050. Even the Democratic Republic of Congo, Ethiopia, Tanzania, Bangladesh, Indonesia, and Pakistan are projected to increase their urban population by more than 50 million each.

In some countries, such as Brazil, Pakistan, and Kenya, there are already more children growing up in slums than non-slums. UN Habitat State of the Cities Report 2012/2013 shows a graphic of the proportion of persons in cities without electricity. On a global level it is around 10 percent or by simple math 200 million persons. In Africa, the proportion without electricity in cities is more than 70 percent. The backstory is that many of these light their homes with unsafe, stolen electricity, or worse, with candles and kerosene.

As electrification expanded across developing countries in the 20th century, slum electrification began as a way to provide electricity in informal urban and peri-urban areas to make them safer (from fires), healthier and more livable. Often service was provided free or at very low prices (below cost) as social support. Few could afford more than a than a lightbulb at that time.

But as slums grew rapidly and more structures were connected (sometimes by on-selling and/or illegal connection) and appliances dropped in prices, electricity companies found that they were unable to afford their government's beneficence at the expense of paying customers. Low-cost efforts to regularize slums and stem the mounting losses began with mixed results. Fixed price services failed when the regularized customers failed to pay. Load limiters were bypassed. Monthly billing was difficult to collect and failed as well.

By the turn of the century, urbanization was on a roll, and non-technical losses to electricity companies had mounted sometimes as high as 30 percent of served electricity (of which informal communities often contributed a major portion). Simultaneously, governments were reforming their electricity sectors, often privatizing them, and creating regulatory bodies to manage the electricity sector in order to reduce the costs that governments had formerly borne and passed on to taxpayers. Performance contracts (or partial privatization which brought some business rigor to otherwise lackadaisical management) were instituted to spur efficient practices, and limits were placed on the return that companies could expect from billed customers.

By 2004, a number of companies had managed through pilots and trial-and-error to start turning around the losses. Recognizing that informal communities and residents were far more marginal than areas where development had been controlled, they adjusted their service approach to the realities of such areas. Also in 2004, USAID began documenting these successes in Brazil (COELBA, LIGHT), India (Ahmedabad Electricity Company), South Africa (PN Energy), and the Philippines (MERALCO). In 2005, USAID and the World Bank co-sponsored a slum electrification workshop in Brazil, inviting these successful companies and

FIGURE B.2.1 Infrastructure coverage by region

Percentage of urban population with electricity

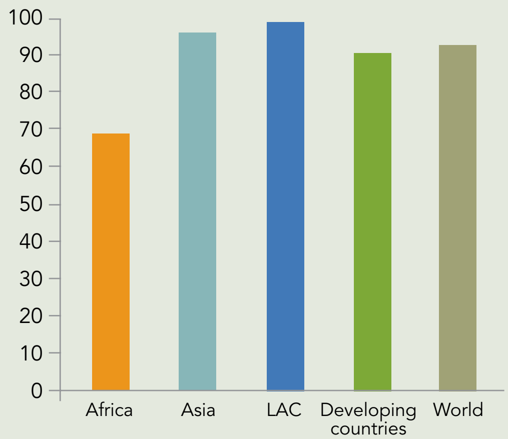
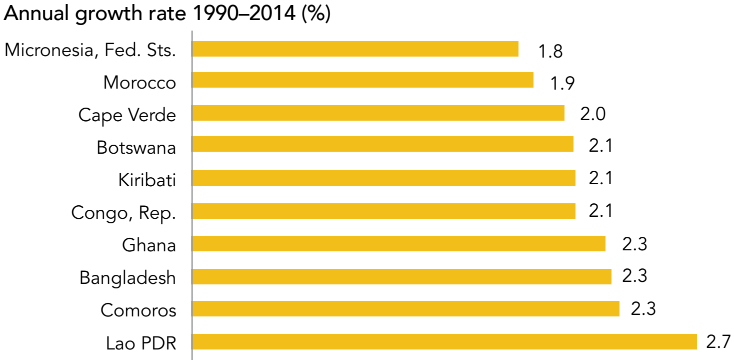


FIGURE 2.5 Morocco and Bangladesh are among the fastest growers in access to electricity

(Incremental percentage point in access to electricity, 2000-2014)

Annual growth rate 1990–2014 (%)



Source: Data from IEA and World Bank 2017

Rural Electrification Board. But by the early 2000s, the pace of electrification was not fast enough (despite 400,000–500,000 connections per year), costs were increasing, and insufficient generation resulted in frequent power outages.

In 2003, in an effort to find a more cost-effective solution for remote households—one that complemented grid extensions—Bangladesh's solar home system (SHS) program was initiated, providing electricity to 3 million rural households by 2013 (Figure 2.6). At the same time, 1.3 million households received grid electricity through cooperatives. The SHS program opted for the ownership approach, leveraging the strong presence of microfinance institutions (MFIs), which were mostly NGOs, in rural areas. The MFIs were responsible for all aspects of the SHS business (technical, commercial, and financial) and led pay-governments, interested electricity companies, and NGOs to share their experiences. The response was so good that a second conference was held in 2007, vastly widening the number and geographic coverage of the cases where lessons learned from slum electrification were applied.

UN Habitat, the World Bank's African Electrification Initiative and Energy Sector Management Assistance Program began promoting and disseminating these lessons. South-south exchanges brought experts to work with utilities to understand how to design and implement successful slum electrification programs. Case studies on India's TPDDL, LIGHT (Brazil), EPM (Colombia), AES (Brazil), and Kenya Power (KP) were produced. The World Bank's GPOBA's support was instrumental in getting KP to launch its program, but lackluster results were turned around only after exchanges with India, Brazil, EPM, ESKOM, and LIGHT helped KP confront the extreme problems it had encountered in its cartel-controlled slums in Nairobi.

With these lessons, it is now possible to lay out a process with elements that can help an electricity company turn around its losses in informal urban areas and to keep them under control going forward. Essential elements include:

- Strong top management buy-in and support.
- A program management "ownership" approach that puts responsibility on regional managers for success in their region's slums and responsibility for materials and labor support to cover an area comprehensively to avoid falling back into a theft mode,.
- Effective communication with, and engagement of ,the communities—in part by locating personnel in the communities, using community leaders to communicate within their entourage, and employing youth for surveys and when infrastructure works are being implemented.
- Making payment more convenient and affordable (prepayment, electronic payment, social tariffs, on-the-spot bill collection, etc.).
- Investing in a community's basic needs (such as street and security lighting, and electrifying essential facilities like shared latrines).
- Investing in the communities' futures (such as pairing up with water, sewer, roads, and housing improvement efforts).
- A technological approach that makes theft harder and reduces risks from electrocution.

The results are in all cases highly encouraging, with millions connected legally while losses dropped dramatically and revenues increased commensurately. Productive uses tended to increase over time with improving economic conditions, and customers are better able to afford electricity, while company and government images improved.

Maintaining the good results of initial pilots when the numbers of regularizations reaches hundreds of thousands is an ongoing challenge. Continuing support from the other service providers and government brings informal areas up to basic needs and helps electricity companies do their job in an improved environment that creates a receptive community and empowered new "citizens" while reducing the lure of illegal service providers and activities. As those with stolen electricity are converted to legal connections, electricity use goes down to users' "affordable" level, and electricity is used more efficiently. This in turn frees up electricity for others. In cases studied, such as that of India's Tata Power Delhi Distribution Limited, the savings are on the order of 40 to 50 percent of the electricity formerly used. The investment in regularization of electricity use in slums thus brings multiple advantages to society, other electricity users, and those living in slums.

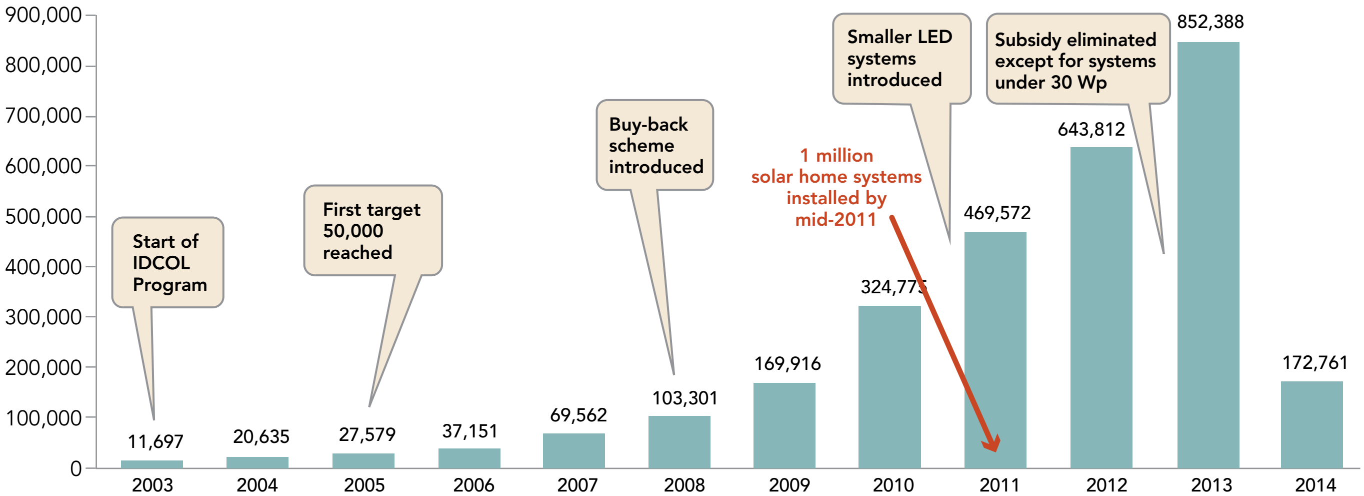
Source: ESMAP Urban Poor Program

ment collection, maintenance provision, and customer training. The government-owned implementing agency, IDCOL, provided training in technology, supplier-selection, and after-sales services. It also offered refinancing at a 6-9 percent interest rate over a 5-7 year repayment period, once installation was verified.

The SHSs were made affordable to households through a combination of consumer credit and decreasing subsidies. Eligible customers were offered microfinance loans, with a 10–15 percent down payment and an interest rate of 12–15 percent over a 2–3 year repayment period. Different system sizes were available to match users' energy needs and willingness to pay. A buy-back guarantee gave customers an option to sell their system back at a depreciated price if the household obtained a grid connection within a year of purchase—although most customers have preferred to keep their solar system, given the electricity grid's unreliability. Initial subsidies were phased out as rural household income increased, and unit cost was reduced thanks to economies of scale, PV panel price reduction, and efficiency improvements. Only a modest subsidy was kept for small systems designed for the poorest households.

Some aspects of the Bangladeshi SHS program may be applicable to other off-grid electrification initiatives. They include: (i) strong pre-existing network of competitive MFIs with deep reach in rural areas; (ii) an entrepreneurial culture; (iii) high density of the rural population, which fostered competition and economies of scale; (iv) rising rural incomes (boosted by remittances from abroad), which stimulated demand; (v) competent implementing agency with strong management and promotion capacity; (vi) tech-

FIGURE 2.6 Bangladesh's successful solar home system program (systems installed each year)



Source: Sadeque et al. 2014

nical and financing solutions tailored to the population's ability to pay; and (vii) adequate consumer awareness and confidence, which was fostered through comprehensive media campaigns and an emphasis on quality assurance.

India's Energy Sector Reforms and Rural Electrification Program

In the period 2000-14, India more than halved the number of people without access to electricity (from 422 to 264 people without access)(IEA and World Bank 2017). In 2014, India's electrification rate reached 79.6 percent, up from 60 percent in 2000—with 70 percent of the newly electrified population resided in rural areas, reflecting both the country's focus on rural electrification and the relative saturation already achieved in urban areas. By 2012, the national electricity grid reached 92 percent of India's rural villages, corresponding to about 880 million people. (Banerjee et al. 2015). Between 2000 and 2014 alone, 400 million people gained access—the biggest absolute increase globally.

The energy sector reforms were initiated in the early 1990s, with the unbundling of the State Electricity Boards—aimed at forming separate companies for various operations (such as generation, transmission, and distribution) and privatizing the distribution companies. In the late 1990s, central and state level regulators were introduced. In 2003, the new Electricity Act, which facilitated an influx of private capital into the sector, was implemented to enhance competition in the distribution sector to ensure an adequate quantity and quality of electricity supply (Krishnaswamy 2010).

Historically, India's rural electrification policies have shifted from line extension to villages in the 1950s, to agricultural production in the 1960s and 1970s, to rural development in the 1990s, and, in 2000, to access for the poor. The government has emphasized electrification in its national policies, and allocated substantial resources, particularly in the past decade, to increasing electricity access (Banerjee et al. 2015). In 2005, it launched the India's rural electrification program, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), with the aim of electrifying all villages and habitations with more than 100 people, installing small generators and distribution networks where grid extension is not considered cost-effective, and providing free electricity connections to households below the poverty line (Banerjee et al. 2015). This program is complemented by the Remote Village Electrification (RVE) program, which is being implemented by the Ministry of New and Renewable Energy (MNRE).

In 2014, around 264 million people, or 20 percent of India's population, remain without access to electricity. In urban areas, electrification rates are much higher than elsewhere, but the quality of service remains very uneven, especially in large peri-urban slum areas (IEA 2015a). The sustainability of the RGGVY program is challenged by underfinanced and unreliable infrastructure providing electricity to the village lines, along with an insufficient revenue stream from rural households to secure a financially sustainable electricity distribution system. Exacerbating matters is the difficulty of pricing electricity appropriately while ensuring household affordability. Thus, solutions are needed to expand electricity access in financially responsible ways that encourage investment in the operation and maintenance of rural systems to minimize supply shortages (Banerjee et al. 2015).

China's Bottom-up Approach to Electrification

Over the past 50 years, China has succeeded in providing access to electricity to 900 million people—with 165 million people gaining access between 2000 and 2014 (IEA and World Bank 2017). The big push began in 1979, driven by economic reforms in rural areas (Peng and Pan 2006), and by 1997, the country was providing electricity to over 95 percent of households (Yang 2003). Electricity access increased further, reaching 99 percent in 2009, driven by the modernization of rural infrastructure and the harmonization of rural/urban consumer tariffs. As a result, in 2009, the deficit was down to 8 million people, out of a total population of 1.3 billion (Bhattacharyya and Ohiare 2012). Nonetheless, rural electricity consumption per capita in 2008 was just 30 percent of China's average electricity consumption, suggesting that the rural electricity market has not reached saturation.

China has relied on a bottom-up approach to electrification, with local administration responsible for the local solution. Each county created a rural electrification committee (led by the county governor), which made decisions on rural electrification investments and operation, while overall program planning was kept at the central level.

The solutions have involved a mix of grid extension and off-grid options—with rural electrification relying on three modes of delivery: local grids, central grid, and a hybrid system (Pan et al. 2006). Although the central grid remained the main mode of supply, local grids played a key role in areas with large hydro potential, with county water bureaus or small hydropower companies, responsible for electricity supply. Incentives targeting small hydropower, such as a reduced VAT rate and state investment funds, also helped. Stand-alone systems were disseminated through distribution companies that procure major components from manufacturers directly, small assembly shops selling directly to installers, and retailers selling directly to end users (ESMAP 2000). Technological flexibility has allowed local resource utilization and avoided the highest-cost options for difficult locations.

China has electrified remote areas through a phased approach, based on pilot projects and capacity building. In 1996, the Brightness Program started with pilot projects, installing over 5,500 SHS, and over 500 wind and solar hybrid systems at a cost of $50 million (Shyu 2010). In 2002, the Township Electrification Program was launched to scale-up pilot projects to extend electricity access to over 1,000 townships in 11 western provinces (Shyu 2010). It relied on 13 system integrators, chosen through a competitive bidding process, who designed, procured and installed the systems, while the service companies were responsible for operation and maintenance. By 2005, over 840,000 people had gained access to electricity (Bhattacharyya and Ohiare 2012).

FUTURE OUTLOOK OF ELECTRICITY ACCESS

The outlook for access to electricity shows that the world is far from being on track to meeting the SE4All goal of universal access to modern energy by 2030 (Figure 2.7). When the 2030 Sustainable Energy for All objective of universal access was announced, it was estimated that the global rate of access to electricity would need to increase by 0.8 percentage points each year throughout 2010–30. But because progress has fallen consistently short of this rate since 2010, efforts in the remaining years need to be stepped up to 0.9 percentage points.

Under the IEA's latest World Energy Outlook New Policies Scenario, around 780 million people will remain without electricity in 2030—increasingly concentrated in sub-Saharan Africa, which will have around 80 percent of the global total at that time (IEA and World Bank 2017).

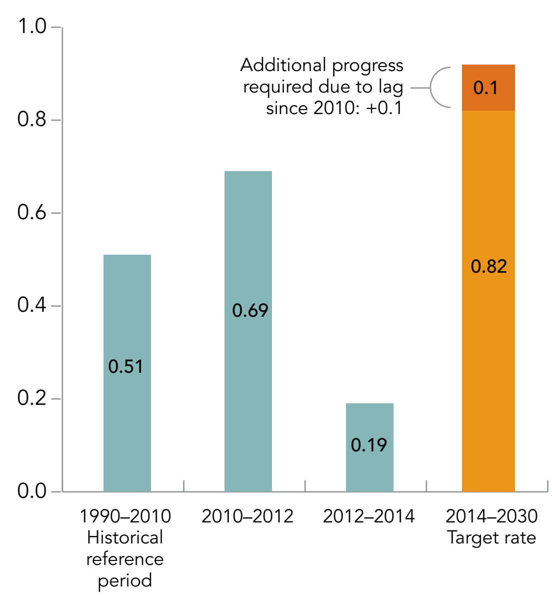
Yet universal access to modern energy services is still some distance away and will require that countries expand access more rapidly than demographic growth. Universal access to electricity requires an even higher annual pace of growth of 161 million people from 2014 through 2030. Although the access deficit in 2014 was overwhelmingly rural, the forecast population increment is almost entirely urban (Box 2.1) (IEA and World Bank 2017).

At the regional level, Latin America and Caribbean, East Asia, and South Asia will be able to reach universal access to electricity by 2030, assuming conditions of constant growth in electricity, constant growth in population, and no major changes in political willingness and financial investments to increase access (Figure 2.8). However, Sub-Saharan Africa is falling behind—currently growing at 5.4 percent annually, against the needed 8.4 percent annually to reach universal access by 2030.

The last figures published by the IEA (IEA, 2011) on comparable estimates of current financing trends and future investment needs for achieving universal access to electricity provided a high-level estimate of investment needs of $45 billion a year, against actual investment flows at that time of an estimated $9 billion a year.

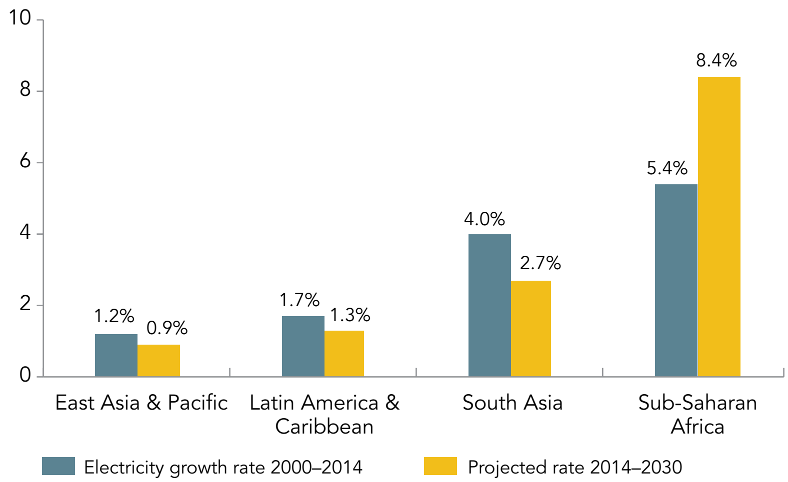
The World Bank's Access Investment Model provides rather detailed bottom-up estimates of the cost of reaching universal access in each of 15 countries with large electricity access deficits. They reflect differences in population and geography across countries as well as local unit costs, and can be extrapolated to give a global estimate of access investment needs (IEA and World Bank,

FIGURE 2.7 Access falls short of the pace to meet the 2030 target



Source: IEA and World Bank 2017

FIGURE 2.8 Latin America and Asia on target for electricity universal electricity access by 2030



Source: Data from IEA and World Bank 2017.
Note: The estimates assume conditions of constant growth in electricity, constant growth in population, and no major changes in political willingness and financial investments to increase access.

2015). The model, based on the Multi-Tier Framework (World Bank, 2015) allows users to choose the tier of access that would be used to meet the universal access target, and illustrates how dramatically this affects the costs of electrification. Reaching universal access at Tier 1 (enough to light a few light bulbs and charge a mobile telephone) would require investments of $1.5 billion annually up to 2030. By contrast, reaching universal access at Tier 5 (full 24x7 grid power) would require investments of $50 billion annually.

GETTING BETTER MEASURES OF ELECTRICITY ACCESS

Currently, electricity access is defined and measured with binary indicators—that is, yes or no on "having a household electrical connection," "using electricity for lighting," or "cooking with non-solid fuels" (World Bank and IEA 2013). This approach was a reasonable first effort on balancing the ideal metric that best captures progress in the energy sector with the constraints posed by the need to use data, and it is the one that was used in the SE4ALL GTF reports released in 2013 and 2015 (World Bank and IEA 2013; World Bank and IEA 2015).

Such binary indicators can easily be obtained through household surveys with a very small number of questions, but they fail to capture the multi-dimensionality of electricity access—and thus misrepresent the scale of the challenge. For electricity, they do not provide any insight on the quality, reliability, affordability, or legality of what is being supplied.

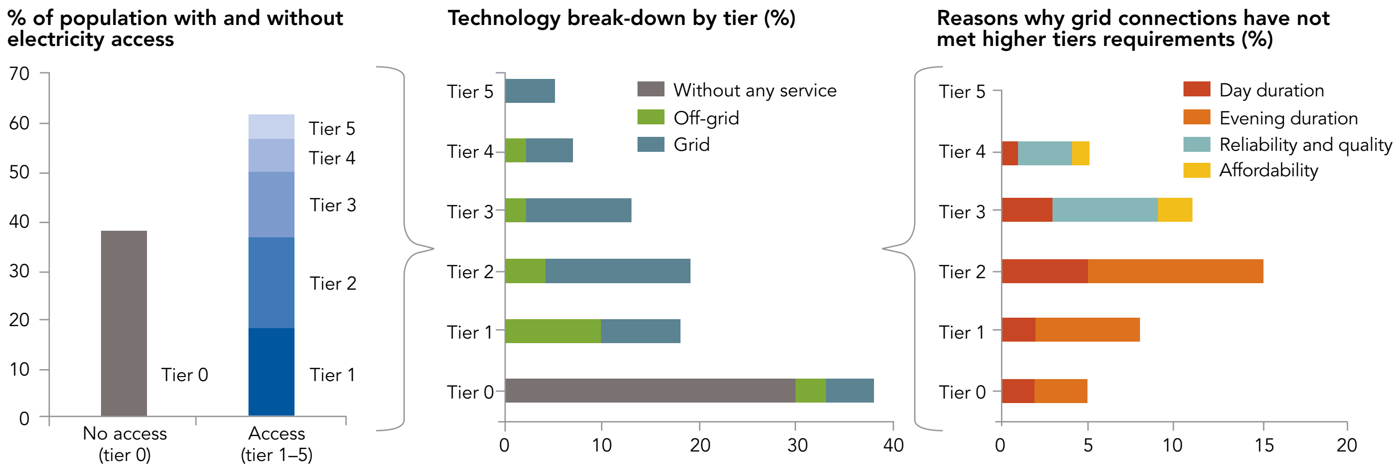
What is needed now are indicators that can capture two aspects: (i) all technologies (mini-grid, off-grid solutions, and main grid connections), based on the performance of each solution in terms of quantity and quality of electricity supplied. That is why the multi-tier framework (MTF) for measuring electricity access was recently developed in partnership with a large number of stakeholders, under the umbrella of SE4ALL. It measures access across five tiers (zero being the lowest and five being the highest) and eight attributes (capacity, availability, reliability, quality, affordability, legality, convenience, and health and safety), encompassing all energy sources used within households, productive uses of energy, and community facilities. Based on the combination of multiple attributes of energy supply, higher tiers feature progressively higher performance, as the energy supply accommodates an increasing number of energy applications, or delivers improved user experience (World Bank 2015).

For policymaking and investment decisions, the advantages of the MTF are many: (i) it provides more accurate data on the actual level of services that end users receive, and tracks progress in providing access to reliable, affordable, and modern energy services at both national and program levels; (ii) it enables a detailed analysis of current energy usage and provides other relevant supply and demand data for both electricity and clean cooking; and (iii) it provides more granular and disaggregated data, which facilitates targeted interventions that could move users to higher tiers. As a result, it will be possible to determine the key reasons holding back the country from achieving higher tier levels. It can also track contributions to access from upstream investments, such as generation and transmission. And it allows setting country-specific realistic targets for universal access, which account for a country's initial conditions and the timeframe for achieving targets.

Take the case of a country that has still needs to sharply step up access to electricity, as illustrated in Figure 2.9. A binary approach would show that about 40 percent of the population lacks access to electricity, while 60 percent has it. But the MTF may show a different electricity access level—either higher (if the binary indicator does not account for off-grid solutions) or lower (if grid-connected households are not receiving a minimum number of hours of supply to qualify for Tier 1, which would be at least 4 hours a day and at least one hour in the evening). It also sheds light on the key reasons holding the country back from achieving higher tier levels. For example, a large number of grid-connected households could be moved from Tier 0-2 to Tiers 3–5 if the duration of service, especially in the evening, could be increased.

Since 2012, the MTF approach has been piloted in several areas (for example, Kinshasa City) to test the methodology, and by end-2016, the "Global Survey for Multi-Tier Energy Access Tracking" will be launched in about 15-30 countries that have high access deficits. The results will help policymakers determine gaps in the performance of the energy supply, identify types of interventions and financial investment requirements required, and set the baseline to track progress toward ensuring universal access. Open-Source Country Energy Databases will be accessible after the implementation of the MTF global survey by the end of 2017.

FIGURE 2.9 Multi-tier framework tells much more about electricity access



Source: Introducing Multi-Tier Approach to Measuring Energy Access https://www.esmap.org/node/55526

CONCLUSION

So where does the international community stand on achieving universal access to modern energy services by 2030? As the latest GTF binary indicators show, in 2014, 15 percent of the population still lacked access to electricity despite some successful initiatives across several technologies. Clearly, the pace of growth has to be accelerated to achieve universal access by 2030: each year, 161 million people need to be electrified from 2014 through 2030.

One tool that would help facilitate the effort would be a new way of measuring the electricity access target, beyond the traditional binary metrics—which can be misleading because they do not capture the multi-dimensionality of access and thus misinterpret the scale of the challenge. The World Bank and ESMAP are working with partners to promote broader adoption of the MTF as the key monitoring platform for tracking progress toward SE4ALL goal and Sustainable Development Goal 7—ensuring access to affordable, reliable, sustainable, and modern energy for all.

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CHAPTER 3

CREATING A BETTER ENVIRONMENT FOR TRANSFORMATIVE ELECTRICITY ACCESS

KEY MESSAGES

- In successful cases of transformative electricity access, public financing support has played a vital role in the initial stages of grid-based electrification programs.
- Best practices for successful grid-based implementation include: sustained government commitment, dedicated institutions, predictable financing mechanisms, realistic measures to ensure affordability and sustainability, and electrification programs that fit into a broader vision of social and economic transformation.
- Mini-grids can supply "grid-quality" power to communities quickly, but they must address challenges—such as high upfront investment, regulatory uncertainties, tariff differential issues, the stranded assets problem, management and operations capabilities, supply and demand mismatch, and the need for productive load.
- For the private sector to play an increasing role in financing mini-grid interventions, there must be incentives in place to allow investors to make returns on their investment.
- Given that scaling up access is influenced by context, it is critical to carefully weigh regional perspectives and encourage each country to choose its own pathway.

INTRODUCTION

What are the challenges and drivers of transformative electricity access? More than 70 countries have been working over the last four years to develop action plans, strategies, and projects to deliver on the international community's goal of universal access to modern energy services—as spelled out in the Sustainable Energy for All (SE4ALL) initiative and the UN's Sustainable Development Goal 7 (SE4ALL, 2016). Their efforts have been supported by partnerships and initiatives from both the public and the private sector that have emerged at the national, bilateral, and multilateral levels.

What is holding up more progress being made? The key hurdle appears to be creating an enabling environment for an energy access roll out. While no single recipe exists, the evidence points to some facilitative ingredients that are foundational—including the right institutions, strategic planning, strong regulations, and appropriate incentives. This chapter tries to provide some entry points to help energy planners, policy makers, and other stakeholders find ways to create the needed enabling environment. It begins with a discussion of the two complementary tracks to universal access to modern energy services—grid based and off-grid—followed by the key challenges associated with each one of them. It then outlines some measures and tools to plan for complementarity of grid and grid solutions. And, finally it provides some insights on how to make access transformative.

GRID AND OFF-GRID: TWO COMPLEMENTARY TRACKS TO UNIVERSAL ACCESS

Meeting increased energy demand, which is linked to universal, basic and affordable energy services can be achieved following two complementary tracks: (i) ensuring grid-based electrification, where the grid is extended beyond urban and peri-urban areas; and (ii) ensuring off-grid electrification by establishing community level micro- or mini-grid systems, or using isolated devices and systems at the household level. Each of these tracks operates at different scales and provides differing energy services, features varied capital requirements, and serves specific types of customers and population densities (Table 3.1).

Grid electrification. The expansion of national electricity grids is the "conventional" method of expanding access to energy services. It involves adding power plants and electric utilities and expanding high-voltage transmission lines and

TABLE 3.1 Two technological tracks for expanding energy services

CHARACTERISTICS	GRID ELECTRIFICATION	OFF-GRID ELECTRIFICATION	
Systems	Centralized	Micro-grids and Mini-grids	Stand-alone systems
Scale	National, regional, and even international	Community	Household
Geographic radius	More than 50 square kilometers	1 to 49 square kilometers	< 1 square kilometer
Number of customers	Thousands to millions	Dozen to hundreds	Usually a dozen or less
Installed capacity	More than 10 MW	20 kW to 10 MW	< 20kW
Technologies involved	Large-scale and centralized	Medium-scale and small-scale	Very small-scale
Investment required	Billions of dollars	Millions of dollars to hundreds of thousands	Thousands of dollars

distribution networks into rural areas, "its tendrils reaching out into the countryside and bringing with it opportunities for jobs, communication, improved education, better health and a host of other welfare improvements."

In the past two decades, more than 1.7 billion people have been added to national electricity networks worldwide, mostly in urban areas (Figure 3.1). Although a lot of progress has also been made in rural areas, the numbers connected are not rising as fast, because rural electrification involves connecting villages incrementally to the existing grid, with remote areas with small populations, high line losses, and low usage levels usually the last to be served. National electrification programs in Chile, China, Mexico, the Philippines, and Tunisia, for example, were implemented through grid extension activities that involved operationalizing large-scale power plants and grid networks.

Off-grid electrification. Energy services can also be expanded using "off-grid electrification," which involves much smaller grids than in "grid electrification."

- One approach is a "mini-grid." It is a localized or isolated grouping of electricity generation, distribution, storage, and consumption within a confined geographic space. Though definitions vary, these grids are often locally managed, have less than 10 MW of installed capacity, serve small household loads, and cover a radius of 50 kilometers or less. They can be connected to a national grid, but typically, they operate autonomously and are better suited for communities where there is sufficient demand throughout the day and year-round.
- Another approach is a "micro-grid." It typically operates with less than 100 kW of capacity, has even lower voltage levels, and covers a three to eight kilometer radius.

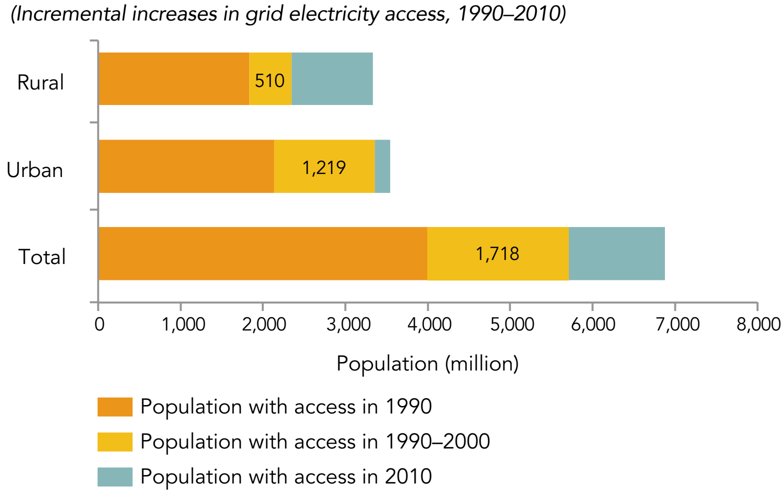
Both of these can be powered by fossil fuels, using diesel generators or fuel cells, or renewable energy sources (like micro-hydro dams, solar PV plants, biomass combustion, and wind turbines). A clean energy technology mini-grid may comprise a single power source (like a small hydropower plant), or a hybrid system with renewable energy sources with batteries or a diesel generator.

When configured properly, mini- and micro-grids can operate more cost effectively than centralized generation and distribution. That is why diesel-power and small hydropowered mini-grids have been used for many decades. In Indonesia, many of the 6,000 inhabited islands are powered by diesel- or small hydro- mini-grids; and a few are retro-fitted with solar PV systems to avoid high-cost diesel fuel. In the Maldives, about 200 inhabited islands and all resort islands are powered by diesel mini-grids. Plus, some of these are being converted into solar-PV-diesel mini-grids, as part of the government's strategy to transition to 100 percent renewable energy-based economy.

In very remote communities, energy services can be provided with "stand-alone" systems, which can be deployed usually far faster and with less complexity than a mini-grid. Increasingly, small PV systems (called "pico" solar systems), using a few watts of solar PV to tens of watts, provide high value lighting and mobile phone services. In directly coupled configurations, they provide motive power for activities like water pumping, grain milling. And stand-alone PV systems with batteries also offer a highly reliable electricity supply for telecommunications base stations where reliable grid supply is unavailable.

Moreover, in recent years, the stand-alone electricity product market has been expanding rapidly—and is expected to continue to do so.

FIGURE 3.1 A big push in electrification since 1990
(Incremental increases in grid electricity access, 1990–2010)



Source: Bazilian 2013.

- Navigant Research estimates that the market for solar PV products will grow from about $550 million in 2014 to $2.4 billion in 2024.
- Off-Grid Solar Market Trends Report 2016 notes that this market has shown impressive growth in the past five years, with more than 100 companies having sold about 20 million branded pico-solar products (mainly portable lights) by 2015 (Bloomberg New Energy Finance and Lighting Global, 2016). The report also estimates that about one in three off-grid households globally will use off-grid solar by 2020.

EXPANDING GRID-BASED ELECTRIFICATION

What are the key challenges to expanding electricity from the grid? Many reviews have identified key challenges to expand electricity from the grid, ranging from insufficient power generation capacity to high customer connection charges (Barnes, 2007; Bazilian et al, 2010; World Bank, 2010; World Bank, 2011; Eberhard et al, 2011; Sovacool, 2013; Banerjee et al, 2014; World Bank IEG, 2015).

Insufficient power generation capacity. Many countries in Sub-Saharan Africa and South Asia often experience load shedding in a context of growing demand for electricity services—with power shortages costing Africa 2-4 per cent of GDP annually (Africa Panel Report, 2015). Considerable load shedding is reported in Nepal (where power deficit was 30 percent in 2013), Pakistan (where 42 percent of employees faced 4-8 hours power cut daily), and India (where the electricity deficit was 54 TWh and the power deficit was 3.4 GW in 2014–15).

Poor transmission and distribution infrastructure. Many decades of under-investment, poor governance in the energy sector, and, in some cases, conflicts and civil wars, are hampering the development of adequate transmission and distribution infrastructure. In a business-as-usual scenario, some rural communities could wait for 20 to 30 years to have access to grid-based electricity. Meeting Africa's increasing demand for power will require significant and sustained expansion of the generation capacity—at a rate of 7,000 MW each year—as well as transmission and distribution systems. This is expected to require mobilizing about $41 billion—roughly 6.4 percent of the region's GDP. Currently, spending is estimated at under $5 billion per year, mostly focused on operating and maintaining existing infrastructure, leaving a huge financing gap in power sector expansion.

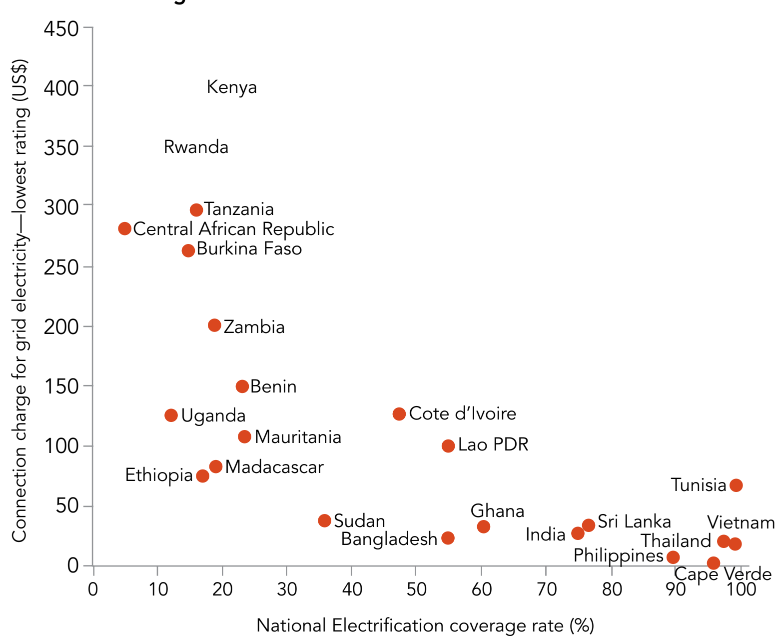
High costs of supplying consumers in rural and remote communities. Many rural communities are characterized by a low population density and a very high percentage of poor households. Demand for electricity is usually limited to residential and some agricultural consumers. Many households consume less than 30 kilowatt-hours (kWh) per month. The combination of these factors results in high average costs of supply for each unit of electricity consumed. Often grid extension to these communities is prohibitory expensive and technically challenging due to remoteness—and even geo-physical constraints, which result in unique power markets and transmission constraints inherent in islands and archipelagos that are highly vulnerable to natural disasters and climate change-related risks. In the Pacific, the distance between islands and the challenging terrain pose major problems, as most of the island-countries (like Palau) are made up of large chains of coral atolls and islets.

High customer connection charges. Sub-Saharan Africa has the highest number of countries with connection charges higher than $100 per customer at the lowest connection service rating, as shown in Figure 3.2 (Golumbeanu and Barnes, 2013). In some cases (like Kenya, Tanzania, Central African Republic, and Burkina Faso), the unsubsidized connection charges even exceed the country's monthly income per person. Why are the costs so higher for smaller customers? The reasons are many: (i) weak commitment of utilities to provide electricity access to rural customers, (ii) inadequate electrification planning, (iii) high investment cost for providing electricity connection due to overrated technical specifications for low loads, (iv) inefficient procurement practices, (v) low population density, and (vi) lack of financing options to make connection charges affordable. Exacerbating matters are various fees for inspection and application procedures, government taxes, mandatory security deposits, and connection charges—and households are responsible for internal wiring, which can run at least $100. Plus, the utilities often charge all these fees upfront, making it difficult for low income households to afford the service.

Poor performance of power utilities. In many countries where electricity rates are low, power utilities tend to have

FIGURE 3.2 Sub-Saharan Africa has highest rates and poorest service

Connection charges and national electriciation rates



Source: Golumbeanu and Barnes, 2013.

not only poor technical and financial performance but also weak governance. This prevents them from being able to provide adequate, reliable, and affordable electricity services to their customers and to expand electricity services to peri-urban and rural areas. Over the past two decades, many countries have pursued energy sector reforms initiatives aimed at improving utility performance issues, but the results have been mixed. In a recent paper on the financial viability of utilities in 39 Sub-Saharan African countries, it was found that only two countries had a financially viable electricity sector (the Seychelles and Uganda) and only 19 countries covered operating expenditures (Trimble et al 2016).

Principles for Model Grid Expansion Efforts

Despite these many challenges to expand grid-based electricity, many countries have managed, or are managing, to implement successful programs—including Bangladesh, Brazil, Chile, China, Costa Rica, Mexico, Morocco, Peru, Philippines, Thailand, Tunisia, Rwanda, the United States, South Africa, and Vietnam. Lessons learned do not lead to a single approach, but they reveal some principles that have contributed to create a favorable environment to develop and implement successful programs.

Government support and commitment. The rollout of a large scale grid-based electrification program is a process that takes time. It requires high level and sustained government support and commitment. Almost every country that has achieved universal electricity access has reached this goal with a strong leadership that established a common national vision of social welfare and economic development with electricity access as a catalytic enabler. In the United States, the 1935 Electricity for All program was part of the New Deal Program, aimed at improving living standards and the economic competitiveness of the farm (Box 3.1). In Vietnam, the highly successful rural electrification program was part of the broader Doi Moi, economic renovation reforms launched in 1986 (Box 3.2). These reforms involved measures to gradually move from central planning to market mechanisms, open up the economy to trade and foreign investment, and reform the agricultural sector. Similar experiences are recorded elsewhere. In Tunisia, rural electrification was rooted in a strong national commitment to integrated rural development, gender, equity, and social equality (Cecelski et al. 2017)—and a high level of government commitment was also observed in China (Han et al, 2014) and Brazil (Jannuzzi and Goldenberg, 2014).

Dedicated institutions and adequate human capacity. Dedicated and operational institutions in charge of planning, financing, regulating, implementing, and monitoring electrification programs are important features of successful programs. According to Howells, 2015, the principal purpose of planning for electrification is to create insights on the issues at stake, appraise policy options, and provide guidance for action, often in the form of an energy plan or roadmap. Certainly, Rwanda's leap from single-digit to double-digit electrification rates, starting in 2009, illustrates how strategic planning pays off (Box 3.3).

Institutions in charge of planning electrification rollout are responsible for determining what technological approaches are applicable and cost-effective—for example, whether it is cost-effective to expand electrification with the grid, or to consider off-grid solutions such as minigrids or isolated systems. The choice of technology depends on many factors, including natural resource availability of a country, availability of appropriate sites, technology output characteristics, and complexity of installation, operations, and maintenance.

Rural electrification can be undertaken by different types of enterprises (public, private, or community-based), each with different incentives. Whereas public companies played a significant role in expanding electricity access in numerous countries (like Lao PDR, Mexico, Thailand, and Tunisia), private and decentralized electrification companies played an important role in others (like Chile). Several

BOX 3.1

U.S. Rural Electrification Transformed Society

Historically, one of the most extraordinary experiences of social transformation is the electrification of rural communities in the United States. In the early 1930s, while 90 percent of urban households had electricity, only 10 percent of rural ones did. Private companies had not been interested in connecting rural households, because the farmers were too poor to afford electricity. On May 11, 1935, the Rural Electrification Administration was created as part of President Roosevelt's New Deal Program. He believed that if private enterprise could not supply electric power to the people, then it was the government's duty to do so.

Rural electrification was based on the belief that affordable electricity would improve the standard of living and the economic competitiveness of the family farm. There were opponents of the program on the grounds of waste of federal funding, but there were also supporters who believed it was the right thing to do for moral and economic reasons. Farmers were urged to create electricity cooperative companies. Electricity fairs were organized to show farmers the uses of electric power at home and on the farm. And low cost financing was made available to farmers to purchase electric powered tools and appliances.

Source: Wohlman 2007; Brodoff 2014.

BOX 3.2

Vietnam's National Drive to Achieve Universal Electricity Access

Vietnam's experience demonstrates that where strong political commitment exists, the goal of universal access to electricity is achievable irrespective of the country's starting condition. This commitment, however, needs to go hand in hand with a willingness to learn from past mistakes and correct one's course when circumstances change.

In 1994, when Vietnam started its universal access drive, its electrification rate was only 14 percent, comparable to the access rates of the least electrified countries in Africa. By 1997, the rate had jumped to 61 percent, and by 2002, it was over 80 percent. Today, the Vietnamese population enjoys the full benefits of electricity, with an access rate over 99 percent.

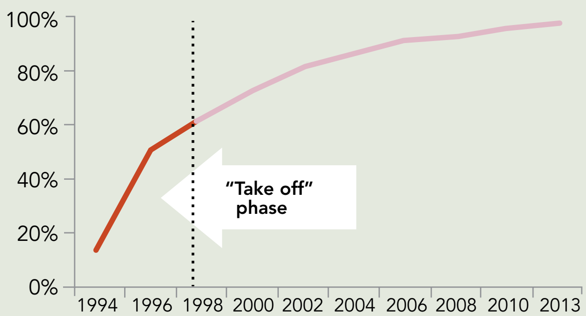
Vietnam's secret to success was not betting on a particular electrification approach, but rather allowing the approaches to evolve over time. In the initial "take-off" phase (1994-97), the goal was to trigger fast access expansion by empowering communities and local authorities to build their own systems. During this phase, little attention was paid to service quality, costs, tariff levels and other regulatory aspects. It was a highly decentralized approach, with a very limited role for the national utility EVN, which was only selling electricity in bulk to these newly created mini-distribution entities. This was a period of extremely fast electrification, with the rate jumping from 14 percent to 61 percent in just three years—as well as record investments leveraged from users, communities and local governments.

However, there was a trade-off between the pace and the sustainability of the electrification efforts. As it turned out, many new distribution networks were of low technical quality and suffered high losses, and the newly established entities did not have sufficient experience nor the financial strength to operate them. The subsequent phases, therefore, prioritized sustainability measures, with a heightened focus on ensuring service quality and both technical and financial viability. Gradually, the dispersed local electrification networks were consolidated into larger units and their operators corporatized; most of them were eventually absorbed by the national utility, EVN.

While many elements of Vietnam's electrification approach are unique to Vietnam, its key lessons are pertinent to all electrification efforts:

- Vietnam has achieved universal access to electricity largely due to the government's unwavering commitment to electrification, and its willingness to learn and when necessary change course.
- Fast progress and a record fund mobilization was possible by making electrification a national priority, engaging central, regional, and local government, along with rural communities.
- Fast progress is not just a matter of political commitment, it also requires a strong demand and a willingness to pay from the participating population—when rural income rose, electrification took off.
- The trade-off between speed and sustainability of electrification efforts needs to be carefully managed.
- Technical standards appropriate for rural areas should be developed and enforced right from the start of the national electrification program.
- Electrification goals should not happen at the expense of the national utility's financial viability.

FIGURE B3.2.1 Electrification Rate in Vietnam



Source: SEAR Case Study: Vietnam's national electrification program, Forthcoming.

countries have adopted the cooperative approach derived from the US experience (like Bangladesh, Costa Rica, and the Philippines). Some others have created Rural Electrification Agencies (REAs) to manage multi-year earmarked resources to support rural electrification projects (like Mali, Senegal, Uganda, and Tanzania). This approach is often accompanied by a rural electrification fund (REF) that is managed jointly or by a separate entity.

Smart regulation of electrification expansion also matters. Successful electrification often requires that the traditional functions of regulation be performed in simpler, non-traditional ways. This is particularly true for off-grid electrification, which is characterized by low revenues in small isolated villages in remote areas where it is difficult to provide services and implement regulation. Regulation of rural electrification schemes is successful if it is adaptive to ensure that a fair playing field is created for electricity service providers to develop cost recovery solutions and for consumers to be able to afford electricity tariff.

Adequate human capacity is also required to implement a successful access program. As indicated by the SEAR Special Feature Paper on The Power of Human Capital (Colombo et al, 2017), "over the last decade, the debate on access to energy has tended to lean mostly on technology, finance, and policy as key drivers. Scaling up the strategies for access to energy requires a different per-

BOX 3.3

Rwanda's Speedy Road to Higher Electrification Rates

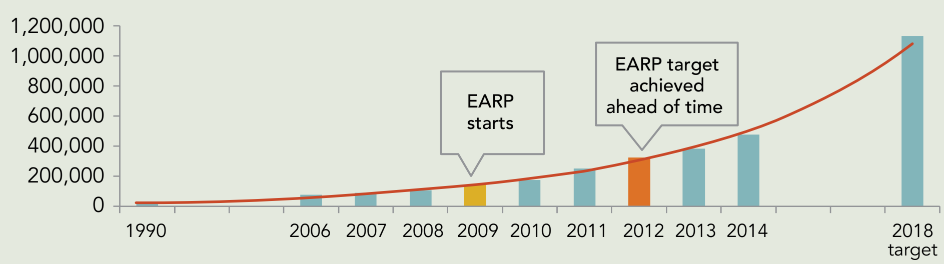
In 1990, there were 17 countries whose electrification rates were still in single digits, but by 2012, this number was reduced to three. Among the countries that made the leap from single to double digits, Rwanda is an undisputed winner, having demonstrated the fastest electrification progress.

Initially, electrification progress was not very fast. Between 1990 and 2008, Rwanda's electrification rate only grew from 2 percent to 6 percent—with electrification efforts hampered by high costs per connection (average $2,000), lack of funding, and uncoordinated electrification efforts. However, the pace picked up in 2009, when the government adopted a new Electricity Sector Wide Approach (eSWAp), with the aim of reaching 16 percent electrification rate by 2013. This approach was underpinned by: (i) an ambitious, yet implementable electrification target; (ii) a geospatial least cost plan; (ii) an investment prospectus to rally existing and new financiers; and (iv) a joint coordination and monitoring system. In addition, technical standards were revised to drive costs per connection down. The SWAp was implemented through the Electricity Access Rollout Program (EARP), executed by the national utility, and financed by multiple donors.

As it turned out, Rwanda's electrification rate rose quickly, meeting EARP's 16 percent electrification target in 2012, rising further to XX percent by 2015 (Figure B3.3.1). EARP II is aimed at an electrification target of 70 percent by 2018, using grid and off-grid solutions. It calls for a new strategy for off-grid electrification, mirroring the coordinated approach applied to the grid rollout—but with greater emphasis on leveraging private sector investments. The bottom line is that better planning, coordination, and new technical standards have resulted in connection costs dropping from an average $2,000 to $880 under EARP I to an average $698 by 2014 under EARP II.

Rwanda's case demonstrates that even countries with very low access rate can successfully, and rapidly, scale up electrification rates. The key factors behind Rwanda's success are: (i) a strong focus on implementation— common target and monitoring system for all development partners, and adherence to the agreed electrification plan; (ii) government leadership and sustained commitment to the program; (iii) geospatial least-cost planning, which has allowed a cost-effective prioritization of investments; (iv) an investment prospectus to help mobilize resources; and (v) affordable connections for households, while lowering costs per connection for the utility.

FIGURE B3.3.1 Rwanda: Cumulative electricity connections



Source: SEAR Case Study: Rwanda—Sector-Wide Planning for Universal Access, Forthcoming.

spective and an innovative approach to capacity building needs to be put in place. In line with the aim of the Agenda 2030 of "no one left behind" and its focus on people, the cross-cutting role of human capital, individually and collectively, as communities and institutions, becomes crucial both as a catalyst and a booster. Indeed, without the proper human resources, accompanying and adapting the process supported by technology, finance, and policy, no progress can be really turned into an efficient and effective, equitable and empowering long lasting transformative change for access to energy." Indeed, adequate human resources are essential for planning, implementing, and monitoring access programs. This is particularly important as electricity access is a long-term process that involves many specialized tasks (such as planning, sustained implementation, operation and maintenance, monitoring, and impact assessment).

Predictable financing mechanisms. Financing mechanisms to support electrification of rural and peri-urban communities vary depending on the electrification approach adopted. When rural electrification is undertaken by the national utility, resources are channeled through the utility to benefit from lower costs—thanks to economies of scale and scope in planning, finance, tendering, investment, and operation and maintenance (Mostert,

BOX 3.4

Using Public Sector Financing for Electrification

- **CHINA:** Strong state support and the ability to engage the local communities to create local infrastructure have contributed to the success of China's near 100 percent electrification. Funds for rural electrification have flowed from the central and local governments, with local residents even participating. The decentralized electrification is either fully funded by the central government or involves a cost-sharing scheme with the provincial government.
- **BRAZIL:** Several programs, with different financing structures, have contributed to Brazil's high rates of electrification. The electrification program PRODEEM was funded by donor agencies and the federal government, while the rural power supply program (LnC) and the Lights for All program (LpT) were funded by the federal government—with the states contributing about 10 percent of the cost.
- **SOUTH AFRICA:** Since 2003, electrification under the Integrated National Electrification Program has been financed by the state budget. Although ESKOM initially thought the electrification program could be self-financed, it became apparent that this was unlikely, prompting the state to take responsibility for funding infrastructure development and subsidizing supply. The improvement in the electrification rate can be partially attributed to the state funding of the program.
- **INDIA:** Under the Rajiv Gandhi Rural Electrification Program, launched in 2005, the electrification rate has risen substantially. The central government provides 90 percent of the funds, and the provincial government provides the rest for infrastructure development. There is also a significant capital subsidy for off-grid electrification projects.

Source: Bhattacharyya 2013.

2008). Over the years, China, Brazil, South Africa, and India have successfully dedicated public funding to support electrification, although each has taken its own approach (Box 3.4).

Affordable electricity services. Determining what is affordable is a complex calculation, typically involving three interrelated dimensions: (i) affordability by consumers for connection fees and consumption costs; (ii) affordability by electricity service providers for operational and financial viability; and (iii) fiscal affordability of subsidies needed for sustainable supply and expansion of electricity access by local and national government (World Bank, 2011). If the electricity tariff is not affordable to potential customers, they will not connect to the service. But if it is too low, the service provider will not be able to collect enough revenues to cover operation and maintenance costs.

To achieve this balance, some countries (Peru and Colombia) have implemented mechanisms to transfer resources from electricity distribution in urban areas to deliver electricity to isolated areas, which meets the conditions of providing affordable rates and sufficient income for the service provider, and also funding for the investment subsidy (IDB,2015). In Chile, the last mile in rural electrification is being achieved by incorporating an income compensation mechanism for service in remote areas. It supplements the income, earned by applying an affordable rate, with a direct government contribution to total revenue for the service provider that is sufficient to keep the system operating.

However, regardless of the approach taken, numerous studies shows that rural electrification expansion requires some form of subsidy—and these subsidies must be efficient, effective, and equitable (Barnes, 2007; World Bank, 2010; World Bank 2011; World Bank IEG, 2015). Many countries have provided subsidies to support initial capital costs of rural electrification infrastructure. These subsidies are used to partially cover the high costs of supply of remote communities and to incentivize distribution utilities or other actors to engage in these settings. The capital subsidy could be determined through competitive bidding in the case of multiple service providers, or as the difference between the unit cost and the willingness to pay of poor households for electricity access. In Bangladesh, a system of subsidies that supports the viability of the electricity cooperatives includes: (i) long-tenor loans, low-interest rates, and five-year grace periods; (ii) a government grant to the Rural Electrification Board, covering one-third of the capital costs; (iii) a low bulk energy tariff; and (iv) cash-flow support to the cooperatives, covering up to five years of operation (World Bank 2010).

Connection cost subsidies are used when the connection cost barrier to electricity services is high even when distribution lines are constructed. The connection charge is defined as the cost to connect the consumer's load to the existent grid. Some connection cost subsidy programs are designed as results-based financing or output-based aid (OBA), meaning that subsidy payments are based on independent verification of outputs, often metered connection and a number of billing cycles. The World Bank, the Global Partnership on Output-Based Aid (GPOBA), and other development partners have been piloting various subsidy schemes to provide the poor with basic services, including electricity (grid, mini-grid, solar home systems) in a number of countries (like Kenya, Ethiopia, Uganda, Zambia, Liberia, Ghana, Mali, Senegal, Bangladesh, India, Bolivia, Laos PDR, and Vanuatu).

DEVELOPING OFF-GRID ELECTRIFICATION SCHEMES

While grid-based electrification may have a role to play in achieving universal access to modern energy services, there is now enormous interest in renewable energy-based mini-grids, as they offer a means of supplying "grid-quality" power to communities quickly without having to wait many years for the distribution network to reach distant communities. Nevertheless, there are challenges that must be addressed to ensure that the mini-grids are the least-cost solution, that they continue to provide affordable electricity services over the long term, and that key risks are mitigated to offer viable business opportunities. Which are the biggest challenges? They cover a wide range of financial, technical, regulatory, and policy issues.

High up-front investment. Renewable energy mini-grids can have high initial costs. These costs are incurred upfront to build the capital intensive power plant to meet anticipated load growth. If demand does not materialize to the same extent or does so at a slower pace, the plant will be underutilized and the revenues inadequate to cover costs.

Regulatory uncertainties. Lenders and investors require regulatory certainty in order to invest in and finance mini-grids and provide services over the long term. Larger mini-grids require regulations to permit third parties to provide electricity services, authorize concessions, adopt tariff setting rules and tariff approval procedures, and to establish safety and service standards. In Rwanda, the government adopted a regulatory framework in 2015 to facilitate mini-grid development (Box 3.6).

Tariff differential issues. Mini-grid tariffs are usually higher than utility provided electricity tariffs, especially for those consuming small amounts of electricity. Unless there is a significant subsidy provided to mini-grids, the tariff charged will need to fully recover the mini-grid investment and operating costs. Even when differential tariffs are permitted, such as in Tanzania or Bangladesh, political realities may prevent charging a vastly different tariff. In Bangladesh, the tariff for the first solar-diesel mini-grid on Sandwip Island was set at $0.40 per kWh, six times higher than the average grid-based tariff of about $0.07 per kWh. Initially, the higher tariff was not an issue, as consumers were running their own expensive small diesel generators. But it became an issue after the Rural Electrification Board (REB) set up its own diesel generation mini-grid on the same island and started charging customers the national average tariff.

Stranded assets problem. Another challenge centers around assets that become obsolete or nonperforming well ahead of their useful life—known as stranded assets. The reality is that if the grid eventually reaches the mini-grid service area, even if the network is built for grid-compatibility, the investment in generation assets may not be recoverable. Thus, policies to permit recovering the investment are needed and some countries have made such provisions.

Management and operations capabilities. The mini-grid is an electric utility business, and as such, requires capable managers and operators. But skilled manpower may be difficult to find and retain in remote locations.

BOX 3.5

Rwanda's Regulatory Framework for Mini-grids

In 2015, in an effort to overcome the regulatory risks that might inhibit mini-grid development, the Rwanda Utilities Regulatory Agency (RURA) issued its "Regulation Governing the Simplified Licensing Framework for Rural Electrification in Rwanda." These regulations support the government's commitment to electrify 22 percent of the population using off-grid means by 2017/18. On the financial side, Energizing Development Rwanda (led by GIZ and financed by donors) offers up to a 70 percent subsidy on investments in privately owned and operated mini-grids of up to 100 kW installed capacity.

Very small isolated grids under 50 kW are exempt from licensing other than notification to RURA. Increasingly, simplified regulations will apply for mini-grids with capacities of 100 to 1,000 kW and small mini-grids in the 50 to 100 kW range. The Electricity Licensing Regulation of 2013 will apply for large mini-grids (above 1 MW).

Importantly, it permits differential tariffs and provides simple required revenue tariff calculation rules: (i) the reasonable costs of operating the grid, including depreciation charges and fuel costs if any, plus; (ii) a reasonable return on the net fixed value of the generation and distribution assets, plus; (iii) a reasonable margin to cover the costs of supply activities; and less (iv) subsidies or grants received specifically for the purpose of lowering tariff levels. The tariffs can be reviewed by RURA if there are customer complaints. However, a complaint based on the fact that the mini-grid tariff is higher than the national grid tariff is not an acceptable reason for review.

Sources: Rwanda Utilities Regulatory Agency, Regulation No. 01/R/EL-EWS/RURA/2015 Governing the Simplified Licensing Framework for Rural Electrification in Rwanda.

http://www.rura.rw/fileadmin/docs/RURA-Simplified_Licensing_Regulations_FINAL_APPROVED.pdf. Mirco Gaul, Rwanda offers a strong policy and regulatory framework for mini-grid, Alliance for Rural Electrification Hybridisation and Mini-grids Newsletter, October 2015. http://ruralelec.org/index.php?id=678#c9526.

TABLE 3.2 Measures to facilitate developing mini-grids

KEY ASPECTS	ACTIONS AND SOLUTIONS
POLICY	Establish a clean set of rules for scaling up the central grid. This is critical for assuring mini-grid operators that they will be properly compensated if and when the centralized grid becomes available.
	Support productive use/enterprise development to increase local abilities to pay for energy, thus increasing demand.
	Provide risk guarantees, tax cuts, or other market incentives to private mini-grid operators.
REGULATORY	Regulation should be light-handed and simplified.
	Establish realistic and affordable quality standards. Standards should address power quality, service quality, and commercial quality to facilitate new connections and accurate billing.
	Delegate mini-grid regulations to an established rural electrification agency. Allow tariff setting and subsidy levels to account for local circumstances.
TECHNICAL	Resource assessment and accurate sizing of the mini-grid is key to providing quality power and meeting future load requirements.
	Adding batteries to hybrid power systems that have variable renewable energy ensures that electric power is available and can provide frequency and voltage stability.
	Local involvement and training is essential for a successful reliable power system from mini-grids. Training and scheduled O&M services can increase life and reliability of the system.
FINANCIAL	Encourage cluster-based mini-grid development to ensure bankability and commercial viability.
	Offer long-term financial support in the form of subsidies, loans, grants, and investment in renewable energy service companies.
	Consider the long-term investment in renewable hybrid mini-grids— typically the least cost solution among mini-grids for most locations over the long term.
	Support parallel creation of productive economic services within the project to help ensure financial viability, long-term project sustainability, and revenues.

Source: Extracted and adapted from Clean Energy Ministerial 2013.

Supply and demand mismatch. Given the seasonality of hydro, solar, and wind, mini-grids powered by these sources will invariably result in under-utilization of the resource because the system must be sized to meet demand during months where resource availability is low. Today, diesels are cost-effective for balancing loads, but they add a high recurring cost. Similarly, batteries are costly. Some amount of demand management can be undertaken where there are loads that can be disconnected during times when resource availability is low. However, a biomass gasifier-based mini-grid is dependent on a year-round availability of fuel at an acceptable price. Thus, there is a risk that once such a mini-grid is built, fuel prices might rise unless there is a diversity of supply within a reasonable transport distance from the plants.

Need for anchor or productive loads. An important justification for a mini-grid and its financial viability is anchor customers and productive loads—especially daytime loads. They can use the power generated when household demand is low and would be willing to pay a premium tariff (less costly than running their own generators). But there are two important barriers to the productive use of electricity: the lack of technical knowledge and skills of potential users and the financial means to acquire relevant equipment (ESMAP 2008). That is why several countries are taking steps to encourage more productive uses.

- In Bangladesh, the potential for productive uses by cooperatives is a key factor in increasing revenues and meeting the requirements to qualify for electrification. Thus, cooperatives are encouraged to engage in productive uses, especially in agriculture (like rice mills and tube-wells).
- In Thailand, the Provincial Electricity Authority (PEA) has successfully promoted replacing diesel motors with electric motors, mostly for rice mills, in villages with lower-than-expected consumption of electricity. To this end, it has facilitated financing for villages to purchase electric motors and other equipment.
- In Cuzco, Peru, there has been a promotional and marketing campaign to encourage productive uses of electricity and develop business assistance in rural areas to promote economic activities utilizing electrical equipment. This region has up to 800 micro-entrepreneurs that are being supported in the adoption or the increase of electricity for productive uses (mainly milling, coffee, cocoa, bakery, dairy products, and carpentry) (Tarnawiecki 2009).

So what can be done to facilitate the development of mini-grids? The possible measures are many, falling into the areas of policy, regulatory, technical, and financial (Table 3.2). One recent study (Walters et al, 2015) that focuses on case studies of public-private partnerships in Bangladesh, Ethiopia, Mali, Mexico, and Nepal, suggests four main areas: (i) establishing an enabling policy development for planning and coordination with clear rules on detailed plans for grid extension and identification of off-grid electrification interventions with regulatory incentives; (ii) catalyzing finance to encourage private sector operators to benefit from a reliable and predictable financial mechanisms (including subsidies, concessionary loans, and reduced taxes and duties; (iii) building human capacity needed at the local level to support interventions; and (iv) integrating electricity access with development programs to enable access to alleviate poverty and to enhance human development.

Along the same lines, GVEP (2011) identifies the following areas: (i) improving policy and regulatory framework with an alignment with rural development goals, a reduction of transaction costs by simplifying licensing and approval schemes, and setting up suitable tariffs and subsidies; (ii) careful considering technical choices to ensure sufficient primary energy resources, design schemes based on local context, and invest in technology development and manufacturing; (iii) securing predictable financing to cover operational, maintenance, and management costs; and (iv) ensuring that all relevant stakeholders are engaged in the project with provisions for capacity building.

Planning for Complementarity of Grid and Off-Grid Electricity Solutions.

In many countries with a low level of electrification access, where both grid and off-grid solutions are being developed, it is important to ensure complementarity of these solutions. Often, off-grid solutions are developed in geographic areas far from the grid to provide communities with electricity services sooner than the grid. Take the case of Cambodia, where, as a study by Tenenbaum et al (2014) explains, there was a lack of policy on what to do when the grid reached the mini-grids. Eventually the situation was resolved by the regulator issuing licenses to transform the mini-grids into distribution utilities—but it underscores the need for planning upfront for the eventual arrival of the grid to give investors more confidence to develop mini-grids in rural and remote areas. The study recommends four options for when the grid arrives:

- Small Power Distributor (SPD) Option where the Small Power Producer (SPP) operating a mini-grid converts to distributor that buys electricity at whole sale from the national grid and resells it at retail to its local customers.
- SPP Option where the mini-grid operator sells electricity to the operator of the national grid but no longer to its local customers.
- Buyout Option where the SPP sells its distribution grid to the national grid operator or other entity designated by the regulator and receives compensation for the sale of the assets.
- Combined SPP and SPD Option where the SPP converts to an SPD and also maintains a backup generator as a supply source to the main grid and retail customers.

Case Study: Ethiopia and GIS Models

What would need to happen in Ethiopia to provide better electricity access and services in a cost-effective manner, combining grid and off-grid solutions? A Special Feature prepared for the SEAR report by Howells et al. (2017) on electricity planning tries to answer this question by using Geographical Information System (GIS) models. These models enable analysts to assess the cost of electricity provision and energy cost implications of competing technological systems in space and time. The use of GIS-based analyses has increased since the mid-1990s with a clear focus on using levelized cost (that is, the breakeven cost) for choosing the appropriate technology.

The Ethiopia study relies on two tools: (i) the ONSSET–GIS-based tool for rural electrification to determine the cost optimal way of providing high levels of electricity access; and (ii) the OSeMOSYS tool to determine the cost optimal way of expanding grid-based bulk generation. The combination of these two tools forms a consistent approach to minimizing the cost of electrification (Bekker et al. 2008) while concurrently meeting the economics of supplying bulk quantities of low cost, reliable electricity. Per capita electricity consumption in Ethiopia is low at 52kWh—compared to 13,246kWh in the United States and 1,743 kWh in neighboring Egypt (World Bank, 2014).

Providing High Levels of Electricity Access

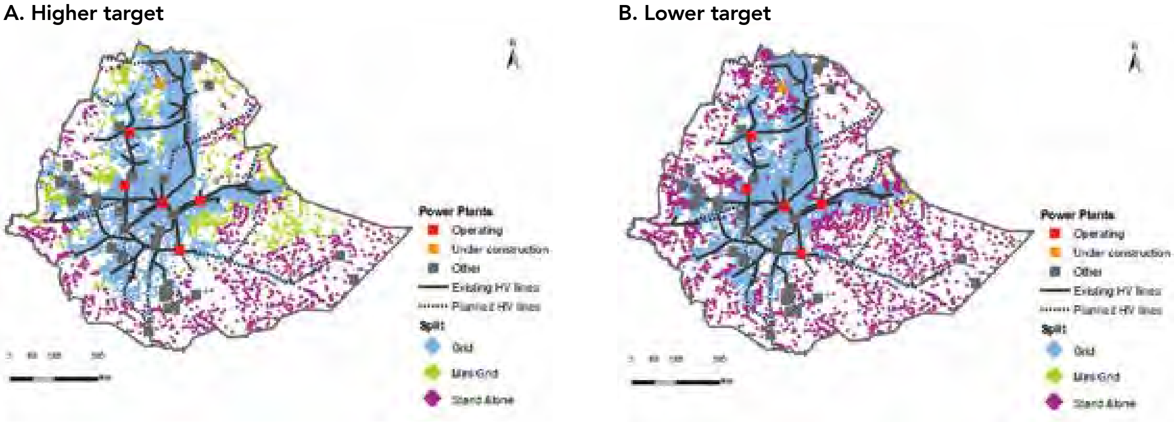
The least cost configuration of grid, micro-grid, and stand-alone technologies to meet two rural (50 and 150 kWh/capita/year) and one urban electrification target (300 kWh/capita/year) are considered. As Figure 3.3 shows, a higher target results in the deployment of grid and mini-grid systems, with remote and low density populations relying on stand-alone electrification. The change in technology from high to low is indicated in Table 3.3, with a noticeably large shift to stand alone systems.

TABLE 3.3 Optimal split for new connections
(Population-based for different rural electrification targets)

SPLIT	POPULATION (150/300)	POPULATION (50/300)	CHANGE
Grid	65,431,650	62,270,395	↘–4.8%
Mini Grid	3,958,695	245,825	↘–93.8%
Stand Alone	656,767	7,530,892	↗1046.7%

FIGURE 3.3 Optimal electrification mix in Ethiopia

A. Higher target **B. Lower target**

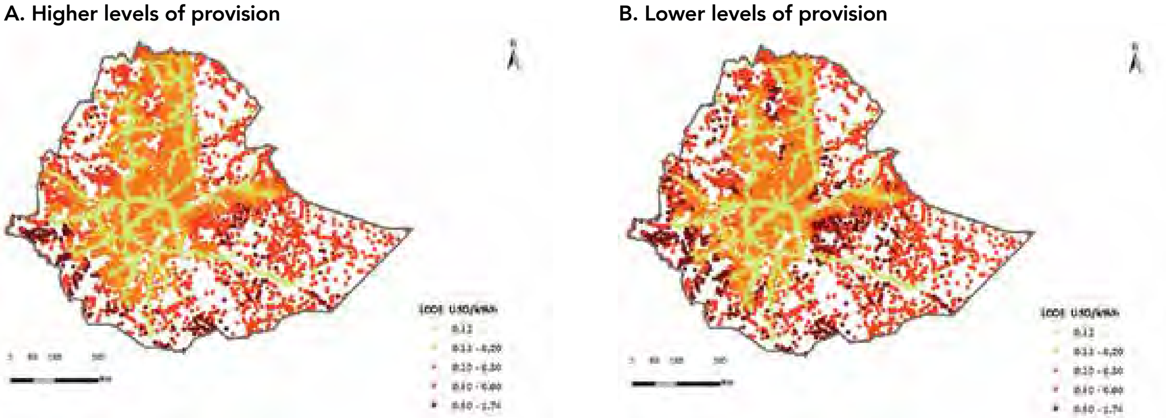


Source: Author's calculation based on Mentis et al 2016 b.

FIGURE 3.4 Higher levels of provision mean lower rural area costs

Spatial levelized cost of electricity

A. Higher levels of provision **B. Lower levels of provision**



Source: Author's calculation based on Mentis et al 2016 b.

Underlying the shift in technology is how the cost of electricity. Figure 3.4 indicates how the levelized cost of supply on a geo-spatial basis changes in response to the higher and lower supply targets. With higher levels of provision, the cost per unit is reduced in rural areas. With lower targets, unit costs are higher. Note that costs near the grid in urban areas remain unchanged, following their constant electrification target.

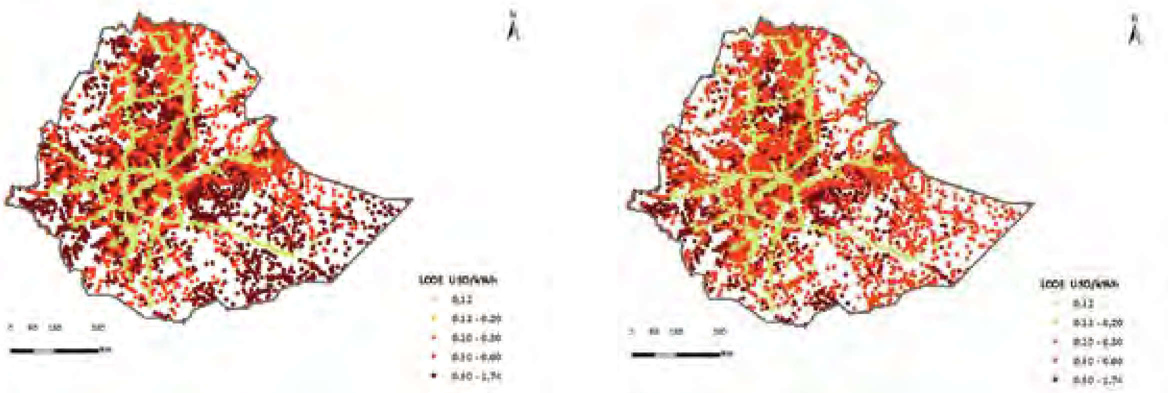
What would happen if electricity costs increase where there is no systematic deployment of solar and mini-grids? As Figure 3.5 (panel A) shows, if the grid is not extended and users only have access to diesel generators, electricity costs are high. But if the PV market becomes more fluid, or the government helps facilitate investment, the cost of rural electrification drops significantly (Figure 3.5, panel B). This occurs because the deployment of PV stand-alone solutions decreases the levelized cost of electricity in some settlements as compared to just diesel stand-alone options. PV stand-alone technology would be more viable than diesel stand alone for 22,624,921 people (or 32 percent of the population that needs to be electrified). If grid extension and mini-grid technologies were to contribute to the electrification mix of the country, only 656,767 people would be electrified by stand-alone systems (diesel, PV).)

Thus, an optimal deployment strategy would include extra grid extension and the deployment of micro-grids—information that could be used to support better policy-making. And knowing the cost optimal deployment characteristics could be used to develop specific policies—ranging from state-led deployment to facilitation of market development. At this point, Ethiopia is undergoing rapid expansion in its generation capacity. Consistent with the most recent eastern African power pool development plan (EAPP/EAC, 2011), the power system grew by 20 percent between 2013 and 2016, increasing by over 4.7GW.

FIGURE 3.5 A case for more grids and PV solar

(Spatial levelized cost of electricity for the electricity access targets 150-300 kWh/capita/year

A. Grid and stand alone diesel **B. Grid, stand alone diesel and solar PV**



Source: Author's calculation based on Mentis et al 2016 b.

Note: Left panel: Population already connected to the grid is grid connected and the rest are electrified by stand-alone diesel.
Right panel: Population already connected to the grid is grid connected and the rest are electrified by stand-alone diesel and PV solar.

One baseline projection (WB) of electricity growth is around 5 percent per year.

Pinpointing the lowest cost route for grid expansion

To determine the lowest cost expansion of the grid-based electricity system, the Open Source energy Modeling System (OSeMOSYS)—which is driven by demand for "grid" electricity resulting from the ONSSET analysis, as well as a national projection of other (bulk) demand growth (based on GDP projections) is used. It captures potential candidate power plants, fuel costs, and resource availability (fossil and renewable) to calibrate the model cost and performance data relating to existing power plants and their retirement schedule. A cost optimal system is then calculated (Howells et al 2011). On the resource front, hydropower is expected to form the foundation for Ethiopia's electricity system (Taliotis et al 2016), although recent analysis (IRENA, 2014) also indicates relatively high potentials of non-hydro renewables available. Plus, there are limited reserves of crude oil and larger quantities of natural gas. The model assumes that newly electrified households meet their demand target of 150kWh per capita in rural areas and 300kWh per capita in urban areas.

Results show that generation investment is dominated by hydro (Figure 6 panel A), with large quantities used for export—although there are significant new investments in capacity required for electrification (indicated hashed lines in Figure 3.6 panel B). But if trade in Africa is to reach its cost optimal potential, Ethiopia will need to join a number of countries that generate significant quantities of electricity for export by 2030 (Figure 3.6 panel C) (Taliotis et al. 2016).

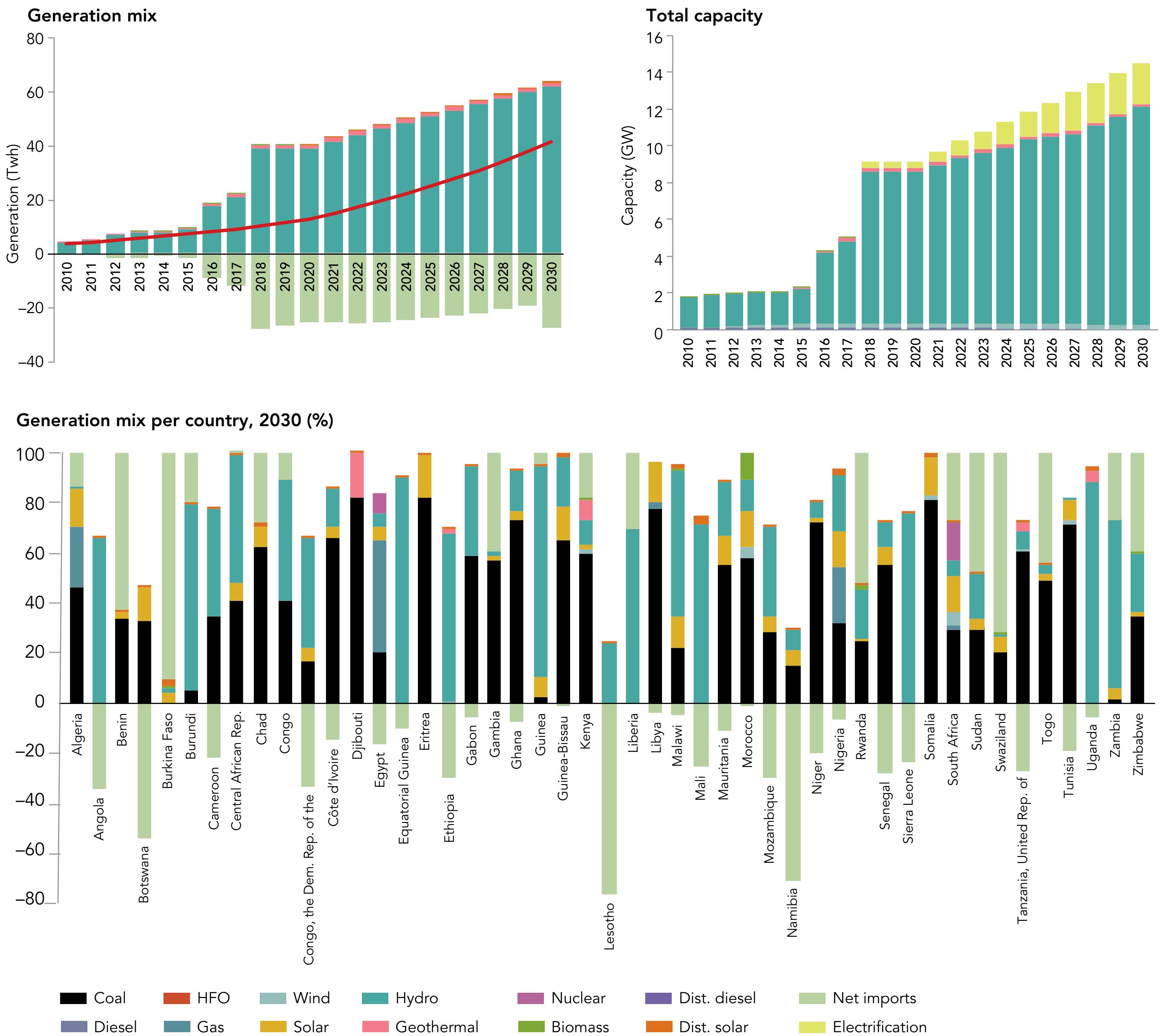
MAKING ELECTRICITY ACCESS PROGRAMS TRANSFORMATIVE

When designing electricity access programs, it is essential to ensure that a holistic view on the ultimate developmental outcomes prevails. But it is also becoming clear that for these programs to be transformative, special attention should be paid to productive uses of electricity services—defined as agricultural, commercial, and industrial activities that require electricity services as direct inputs to the production of goods or provision of services (EUEI PDF, 2011) (Box 3.7).

Often, access to electricity may not automatically enhance productive uses. Enabling activities or business development services might be needed. For example, one study argues that waiting for electrification projects to generate spontaneous positive effects in rural areas appears to be a passive attitude (De Gouvello and Durix, 2008). It suggests a proactive approach to facilitate expansion of productive uses including: (i) identification of the productive activities taking place in a project area and the supporting sectors; (ii) assessment of the potential contribution of electricity in the identified activities and sectors; (iii) technical and economic feasibility and the social viability studies of the identified activities; and (iv) a targeted promotion campaign to potential users about the gains from the use of electricity for a new production process involving various stakeholders (such as electricity service providers, equipment manufacturers, financial institutions, relevant local government entities and community organizations). (EUEI PDF, 2011 provides a manual with a step by step guideline on how to support productive uses of electricity services.)

The promotion of productive uses of electricity in rural areas has the potential to contribute to increasing the productivity of rural business, as well as achieving a more efficient use of the electricity supply infrastructure and

FIGURE 3.6 Hydro will dominate in Ethiopia



Source: (Taliotis et al. 2016) and author's calculation based on Mentis et al 2016 b.

improving the revenues of distribution companies—thereby enhancing the economics of electrification. But there are two important barriers to the productive use of electricity: the lack of technical knowledge and skills of potential users, and the financial means to acquire relevant equipment (ESMAP 2008).

In Indonesia, the rural electrification program implemented by the World Bank in the early 1990s, pioneered the concept of Business Development Services to facilitate productive use of electricity as an integral part of rural electrification program. The project focused on outreach to small businesses through NGOs and developed a marketing strategy for the electricity supplier (Fishbein 2003). The Implementation Completion Report (ICR) of the project (World Bank, 1995) reports that the project created 66,000 enterprises and 22,000 new jobs in food and beverages, light engineering, textile, wood products, rice mills and other agro-industries, small tools and metal products and roof tiles and building materials. However, it is not clear how the information on impacts were collected.

In Peru, the BDS concept was used in a rural electrification project implemented in 2010, which sought to pro-

BOX 3.7

Energy Services Support Agriculture and Food Production

The provision of modern energy services is essential for food production and food security. An increase in access to energy to smallholder farmers would result in:

- Higher productivity and yields via improved efficiency of land preparation, planting, cultivation, irrigation, and harvesting.
- Lower food losses through improvements in processing, providing better quality and quantity of products, requiring less time and effort (via energy supported cooking, heating, storage, preservation, or transformation into higher quality products)—thus adding value.
- Increased earnings from more produce through new market opportunities (such as access to information about pricing).

In order to scale-up the uptake of sustainable energy solutions, practices and behaviors, it is important to align available solutions with local settings. Interventions require a people-centered "bottom-up" approach and need to be better tailored to local contexts, as experiences from energy and agricultural mechanization have shown. More specifically this means to address the following questions:

- What do people want energy for?
- Which types of equipment are used?
- What can people afford?
- What about the capacity to run and maintain the systems?

For poor farmers to reach these goals and achieve higher incomes, there needs to be an improved quality and affordability of energy supplies, an increase in the amount of energy used, and access to a wider range of appliances providing energy services. But since these outcomes are interlinked with non-energy factors – including access to land, water, seeds, knowledge, and market for produce—there also needs to be a holistic approach to smallholders' energy needs.

Source: SEAR Special Feature Paper on Energy Access: Food and Agriculture (Dubois et al. 2017)

mote productive uses of electricity (Finucane et al. 2012). Three NGOs were hired to identify the target areas for productive use of electricity and potential beneficiaries. The role of NGOs was basically to advocate for productive use of electricity as they were paid based on their performance (for example, MWh sold, and numbers of enterprises that increased productive uses of electricity). They assisted small-scale producers and cooperatives to define and assess available business opportunities, estimated cash flow, analyzed the profitability of equipment and electricity infrastructure investments, and created links with buyers, equipment suppliers, and sources of finance and training.

However, the literature on the evidence of productive use of electricity is limited. Some empirical studies (Khandker et al. 2012a & 2012b; Khandker et al. 2013) show that electricity access boosted household employment, or income, or both, but they do not identify the actual productive activities that generated these results. A small number of studies identify some productive activities that helped electricity access in Sub-Saharan Africa and Asia.

- In Kenya, Kirubi et al. (2009) finds that access to electricity extends operating hours of businesses and longer hours for households to produce hand-made goods. It also finds that access to electricity enables the use of electric equipment and tools by small and micro-enterprises thereby improving their productivity (100–200 percent depending on the task at hand) and the revenue of the enterprises (20–70 percent, depending on the product made).
- In India, Chakravorty et al. (2014) infers that access to electricity causes expansion of micro-enterprises that create new employment and income opportunities for the rural population.
- In the Philippines, Barnes et al. (2002) reports that a household survey on rural electrification shows that electricity access enhances the productive capacity through the expansion of small variety stores, tailors and dressmakers, food stands and restaurants, hairdressers and barbershops, carpentry, goldsmith, laundry, etc.
- Enterprises with electricity can benefit not only from improved lighting, but also from electric appliances, tools and machinery.
- Electric machinery and tools can be expensive, but they are more productive, and at the end their benefits outweigh the costs. SEAR Impact Evaluation in Rural Bangladesh consider three measures of outcomes as defined below.
  - Revenue: Annual receipt from the sale of all products and services of the enterprise;
  - Profit: Annual receipt from the sale of all products and services of the entity minus total operating costs; and,
  - Profit margin (P/R): Profit as a percentage of the revenue.

  It was found that grid electrification raises the revenue of commercial. It also increases their profit by 24 percent and profit margin by about 20 percentage points. As for industrial enterprises, grid electrification increases their productivity too. For example, their revenue goes up by up to 55 percent, and profit by up to 60 percent (SEAR Impact Evaluation, Forthcoming).

Several studies have either provided or implied the expansion of productive capacities as they found electricity access increased employment, or income, or both. However, they have not identified the actual productive activities expanded due to the electricity access. While one could expect that providing access to electricity would naturally expand productive capacity, especially in situations where such expansions were suppressed due to lack of electricity supply, there is no guarantee that this process always occurs. Rural and remote areas that are often inhabited by low-income households and lack electricity supply may not have opportunities to expand their productive capacities even if electricity is made available—possibly due to a lack of finance or skills. Thus, it would be more appropriate if some activities to facilitate the productive use of electricity are launched along with the electricity access initiatives—an approach that both maximizes the benefits of the access initiatives and helps long-term sustainability.

CONCLUSION

In sum, delivering on the challenge of universal access to modern energy services is a tremendous endeavor with significant challenges, but already, many countries have successfully organized to overcome these challenges. While recognizing that each country will have to decide on its own pathways to universal access to modern energy services, a central message emerging from this chapter is that of the fundamental role that sustained government commitment plays in the process and how the provision of modern energy services should be part of a broader vision of social and economic transformation.

The fact that many countries have adopted the SE4ALL goal of universal access to modern energy services is indeed an important step forward. These countries should now be encouraged to create or strengthen the necessary enabling environment for action, consider earmarking public sector resources over the medium to long term, and facilitate the leveraging of these resources with private sector financing.

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CHAPTER 4

"CLEAN ENERGY" AND ELECTRICITY ACCESS

KEY MESSAGES

- The cost of electricity from renewable energy has decreased significantly in the past 5 years, becoming increasingly competitive with conventional energy sources. But greater future grid flexibility is now required to allow improved integration of renewables without compromising the quality of supply.
- Clean energy mini-grids have huge potential for supplying electricity to remote areas though they still face many challenges, including the need for appropriate regulations, the demonstration of workable business models, and access to long-term finance. Viable policy frameworks are an urgent need, and many countries are achieving good progress.
- Energy efficiency can reduce the levels of investment required to increase electricity access and to achieve improved reliability of supply. Appropriate sizing of systems and the use of efficient appliances can significantly reduce the barrier of upfront costs for clean energy technology.
- Reduction of costs of renewable energy technologies and adaptive energy efficiency measures offer a tremendous opportunity for countries to think differently and to be creative about electricity access expansion.

INTRODUCTION

Why is it important to explore synergies between access, renewables, and energy efficiency? Much of the world now faces the twin challenges of providing modern energy services and mitigating climate change as countries embark on a new development path to meet the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) (SE4All 2015). The provision of basic electricity access to over one billion people around the world and the subsequent economic development triggered are likely to lead to a significant increase in energy demand. Meeting this demand calls for a major energy shift, driven by the adoption of "clean energy"—that is, renewable energy and energy efficiency—if we are to also achieve the Paris Agreement's goal of limiting global warming to well below 2oC (Lima Paris Action Agenda 2015).

The good news is that clean energy is playing an increasingly important role in the provision of energy services worldwide. Renewable energy technologies are mushrooming across the globe at an unprecedented rate, while the growth in the global economy is starting to decouple from energy-related carbon emissions, thanks to the adoption of energy efficiency measures and technologies (IEA 2015a).

Since 2013, the world has added more renewable energy power capacity (an estimated 147 GW by end-2015 (REN21 2016) than conventional capacity combined (coal, gas, and oil) (Randall 2015). Similarly, there has been a shift in investment patterns: in 2015, global investment in renewable energy power was more than double that in new coal and gas generation (McCrone et al. 2015b). Moreover, for the first time, investment in renewable power and fuel investment in developing countries surpassed investment in developed economies. These positive developments are major milestones in tackling the energy access challenge faced by many developing countries and in reaching universal energy access by 2030 as envisioned by the SE4ALL initiative. As the IEA notes: "If the universal energy access goal is to be achieved by 2030, 55 percent of all new power between now and 2030 must come from decentralised energy sources with 90 percent of it being renewable" (IEA 2011).

Energy efficiency measures and technologies have also helped limit the increase in global final energy demand. In 2014, they cut the increase by almost two-thirds, thereby holding the growth in final consumption to 0.7 percent, rather than the past decade's average 2 percent (IEA 2015d). This, in turn, led to a drop of 2.3 percent in global energy intensity in 2014, more than double the average rate over the past decade. In addition, energy efficiency measures implemented in 1990 in the IEA countries have avoided an estimated 10 billion tons of cumulative emissions, as of end-2014 (IEA 2015b). Investments in such measures across the buildings, transport, and industrial sectors topped an estimated $130 billion in 2012 (REN21 2016b).

Clean energy is currently high on the political agenda—at global and national levels—in both developed and developing countries, with 2015 featuring many high-profile agreements and announcements:

- Commitments by both the Group of Seven (G7) and the Group of Twenty (G20) to accelerate access to renewable energy and to advance energy efficiency.
- Adoption by the UN General Assembly of a dedicated SDG on Sustainable Energy for All (SDG 7).
- Agreement by 195 countries at the UN Framework Convention on Climate Change's (UNFCCC) 21st Conference of the Parties (COP21) to limit global warming to well below 2oC.
- Commitments by a majority of countries at the climate change conference to scale up renewable energy and energy efficiency through their Intended Nationally Determined Contributions (INDCs). Out of the 189 countries that submitted INDCs, 147 countries mentioned renewable energy, and 167 countries mentioned energy efficiency. Some countries committed to reforming fossil fuel subsidies.
- Precedent-setting commitments to renewable energy by regional, state, and local governments as well as by the private sector.
- Pledges by over 100 banks from 42 countries to invest more in energy efficiency projects.

This chapter outlines the benefits of clean energy for electricity access, such as recent and significant cost declines and technological innovations. It discusses how renewable energy and energy efficiency can help provide modern energy services quickly, reliably, safely, and at low cost—including the obstacles to scaling up that must be overcome (like inadequate finance options and unclear government policies). The report concludes that what is needed are a better communication of the advantages of renewables and energy efficiency, more certainty on government policies, public finance mechanisms and innovative sustainable business models, and greater community involvement.

RENEWABLES FOR ACCESS

Renewable energy technologies are flexible, modular, and can be used in various configurations, ranging from those that are grid-connected to those that are off-grid, whether large, mini/micro, stand-alone, or pico (like solar pico PV systems (Box 4.1).

Grid-Connected Renewable Energy

For grid-connected, commercial, or larger scale installations, renewables are a source of energy. Rapid growth, particularly in the power sector, is driven by several factors—including the improving cost-competitiveness of renewable technologies, dedicated policy initiatives, better access to financing, energy security and environmental concerns, growing demand for energy in developing and emerging economies, and the need for access to modern energy. Consequently, new markets for both centralized and distributed renewable energy are emerging in all regions.

- India is planning to add 14 gigawatts of new solar energy every year for the next five years—twice the level of what Germany achieved in its record years of solar investment.

BOX 4.1

Renewable Technologies Come in Various Shapes and Sizes

At utility scale, they provide electricity to meet the diverse needs of grid-connected urban and rural customers. Grid-connected clean energy technologies can range from a few kilowatts of roof top solar photovoltaics (PV) systems connected to the low voltage distribution network, to 10 to 1,000s of megawatts of large centralized utility scale power plants. Examples include hydropower, solar parks, wind farms, geothermal power plants, or biomass-fueled plants connected to medium and high voltage substations. These utility scale renewable energy plants are in place in Ethiopia, Kenya, Rwanda, and elsewhere, providing better quality service to existing customers, as well as widening the reach of the grid to those previously without access.

In mini-grid configurations, clean energy technologies can meet the needs of communities sooner than waiting for grid extension. A clean energy technology mini-grid can be a single power source—such as a small hydropower plant, or a hybrid system with renewable energy sources with batteries or a diesel generator. In the Indonesian archipelago, many of the 6,000 inhabited islands are powered by diesel- or small hydro-mini-grids; recently some are being retrofitted with solar PV systems to avoid high cost diesel fuel.

When communities are small or dispersed and electricity demand is limited, *stand-alone systems*—such as *solar home systems (SHS)*—can be more cost effective, especially when coupled with new business and financial models. Increasingly, small PV systems, known as pico-solar systems (ranging from a few watts to tens of watts of solar PV) provide high value lighting and mobile phone services.

- Jordan passed a new renewable energy law in 2012 that eased the development of large-scale projects. As a result, the country recently finalized funding for seven solar power plants with a combined capacity of 102 megawatts—the largest-ever private sector-led solar project in the Middle East, with five more large-scale projects to follow.
- Sri Lanka and Thailand—developing country "pioneers" that adopted a favorable regulatory environment—are using renewable energy for electricity. Sri Lanka has small (up to 10 MW), private sector renewable energy facilities, and Thailand has 3,000 MW of small renewable energy power plants, equaling about 9 percent of installed capacity.

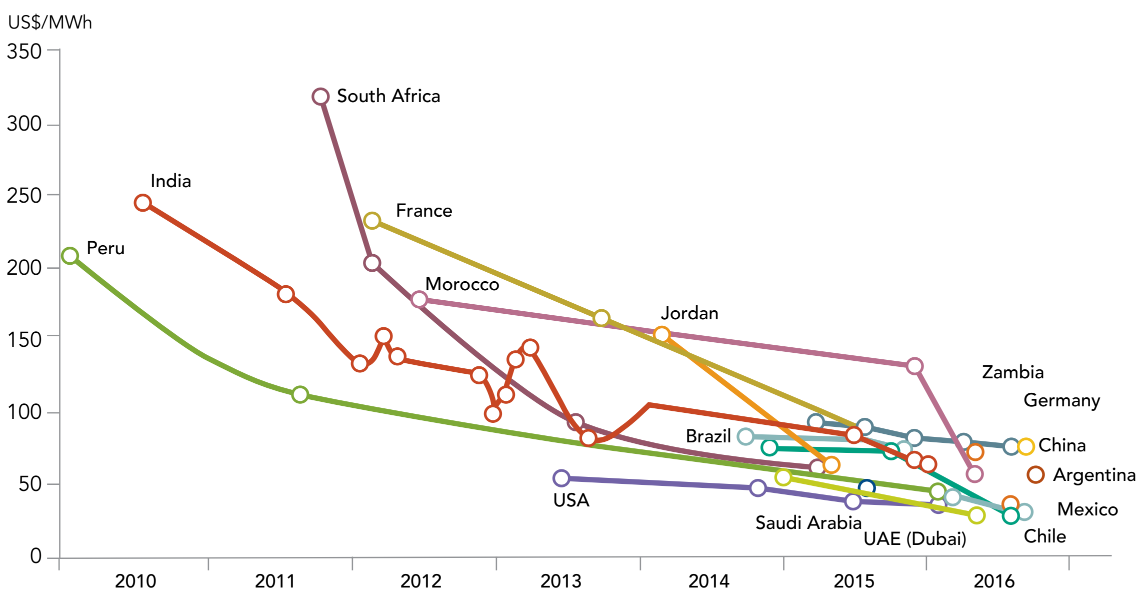
Renewable energy is no longer luxury and is rapidly moving from niche to mainstream. In many areas, it represents the least-cost option to overcome a lack of access to energy services due to significantly reduced technology costs—helped by better procurement practices and incentive structures that benefit from the increased competitiveness of the supply industry and a stronger project developer market. In India, South Africa, and Peru, as Figure 4.1 shows, utility-scale solar PV auctions prices have come down sharply since 2010-2011.

Wind is already often the cheapest form of new power generation capacity. In South Africa, Brazil, India, and Egypt, recent energy auctions have resulted in prices for solar and wind that are competitive with oil and gas, and in some markets they are now competitive with new/greenfield coal. Well-organized tendering processes in some key developing countries—including India, Egypt, Brazil, and South Africa—have proven successful in delivering renewable energy tariffs close to grid parity. Since 2009, South Africa has successfully tendered 7GW of renewable energy announced over four successive rounds. The fourth round, held in 2015, resulted in solar PV prices under $0.07/kWh and $0.05/kWh for wind, which is a substantial decline in comparison with the first round.

The cost of producing electricity (LCOE) from solar and wind has decreased significantly in the past 5 years, narrowing the gap with conventional energy sources (Patel 2015). As Figure 4.2 shows, the IEA reports that the median cost of producing baseload power in 2014/2015 from residential solar was $200/MWh (sharply down from $500/MWh in 2010), compared to about $100/MWh for conventional sources (Patel 2015). But the fall in fossil fuel prices during that time period had only a limited impact on the power sector's cost dynamics. The global average LCOEs for onshore wind eased slightly from $85/MWh in the first half of 2015 to $83/MWh in the second half of 2015, and for solar PV, from $129/MWh to $122/MWh, according to Bloomberg New Energy Finance (BNEF). Meanwhile, the LCOEs for combined cycle gas turbine (CCGT) in Europe increased from $103/MWh to $118/MWh, and for coal, from $82/MWh to $105/MWh (Beetz 2015).

Moreover, many countries have recently announced the long-term contract prices for renewable energy power, notably through preferred bidding exercises, power purchase agreements (PPAs), and feed-in tariffs (FITs), highlighting that even lower generation costs are possible in the coming years. For example, new onshore wind can be contracted for around $60-80/MWh (in Brazil, Egypt, South Africa, and some U.S. states), and utility scale solar PV for around $80-100/MWh (in the United Arab Emirates, Jordan, South Africa, and some U.S. states (IEA 2015c). Furthermore, IRENA estimates that the LCOE of renewable energy options around the world will be at par with—or even lower than—the cost of fossil fuels options, with sig-

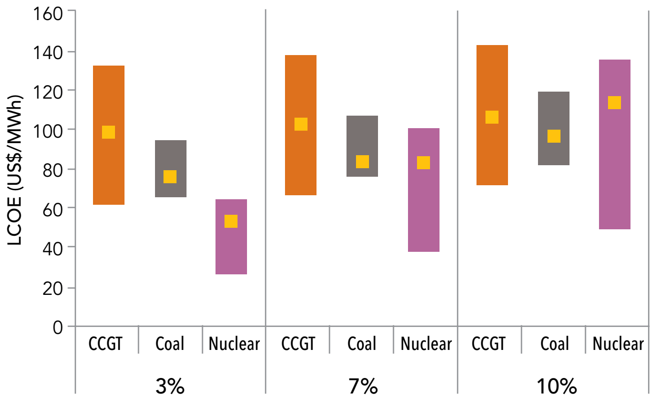
FIGURE 4.1 Utility-scale solar PV auction prices are dropping around the world



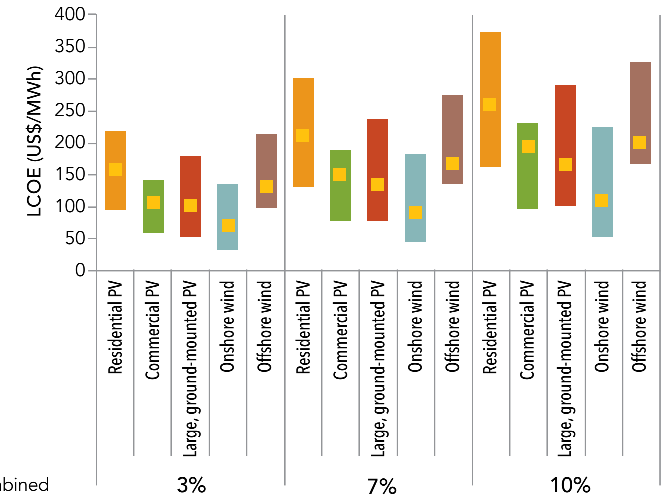
Source: IRENA 2017.

FIGURE 4.2 Renewables now only about double that of conventional fuels

Panel a: (LCOE ranges for baseload conventional technologies, at each discount rate)



Panel b: (LCOE ranges for solar and wind technologies, at each discount rate)



Source: IEA 2015.

Notes: LOCE refers to levelized cost of electricity. In panel a: CCGT refers to combined cycle gas turbine; fuel prices are region specific for the United States, Europe, and Asia; load factor is 85 percent load factor; CO2 price of $30/ton.

nificant decreases expected for some technologies by 2025 (Scott 2015).

As renewable energy continues to gather momentum globally, grid integration is emerging as a key issue to be addressed to accommodate a higher share of variable renewables, such as wind and solar. Many countries have significant shares of power from variable renewable sources—with Denmark leading the pack at about 50 percent—and substantial increases in solar PV and wind expected by the end of this decade (Figure 4.3) (IEA 2016a). Experiences in these countries show that, at lower levels, integration is possible with very little effort (since the additional variability is small compared with the normal changes), and that solutions exist to integrate high shares of variable renewables. However, the current grid infrastructure in many countries was built on the basis of controllable energy sources and organized around the generation–transmission–distribution model (Denholm et al. 2016). In particular, countries with a nation-wide, extensive grid infrastructure need to adapt their operation to increase the flexibility of the system. Countries with new and less developed power systems have the opportunity, to plan, design, and build, from the outset, energy systems and grids that integrate new flexibility concepts and the possibility to integrate high shares of variable renewables.

Flexibility of the power system can be improved mainly through the following four distinct but interconnected channels (IEA 2016a).

Flexible power plants. Power plants need to vary their output to cater for changes in the net load. Variable renewable power can be complemented by dispatchable renewable power. Gas fueled power plants and hydropower plants are the most flexible plants and the least cost option, due to their ability to respond quickly to changes, although hydro's ability is quite often reduced by meteorological events like droughts (IEA—RETD 2015).

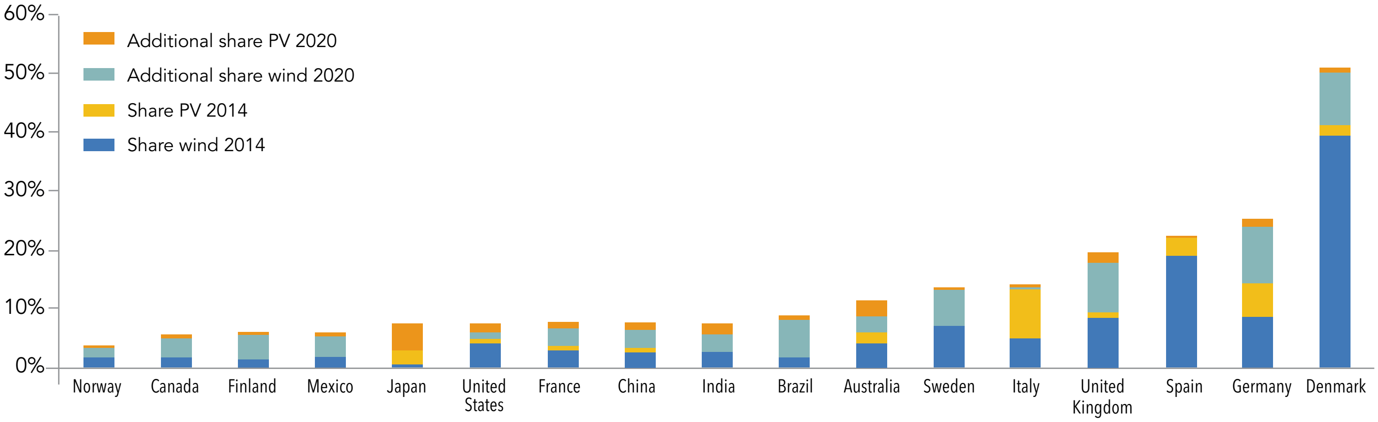
Grid infrastructure. Transforming the grid to allow for a larger share of renewables involves: (i) the bi-directional flow of energy, from power plants to users and from users to the grid; (ii) the establishment of a smart grid to improve responsiveness and reduce peak loads; (iii) the introduction of technologies for grid stability and control; and (iv) grid interconnection, where possible (Martinot 2016). It is estimated that the grid infrastructure option can be achieved at a relatively low cost—for instance, changes in the transmission network may cost as low as $2/MWh (IEA 2016b).

Storage. Electricity can be stored from variable renewable energy sources when supply for the latter exceeds demand, and regenerate when supply is lacking. However, the currently high cost of various storage systems hampers their full deployment. For instance, the capital expenditure (CAPEX) for pumped hydro storage is estimated at $1,170/kW and results in a low benefits/costs ratio when compared to other options (Figure 4.4) (IEA 2014). In Europe, storage capacity accounts for some 5 percent of total energy capacity, 99 percent of which is pumped hydro (IEA-RETD 2015).

Demand side integration (DSI). This refers to the ability to use demand management mechanisms—such as financial incentives and behavioral change through education—to either shift demand away from peak load times or shed loads to match supply with demand (IEA-RETD 2015). DSI usually exhibits the highest benefit/costs performance (Figure 4.5) (IEA 2016b).

FIGURE 4.3 Many countries boosting renewable shares, especially in wind

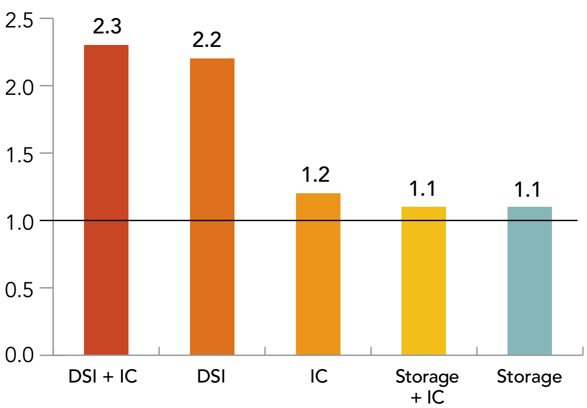
(Share of variable renewable energy generation in selected countries, 2014 and 2020)



Source: IEA.

FIGURE 4.4 Managing demand ranks higher than storage for increasing flexibility

(Benefits/costs ratio of selected flexibility options)



Source: IEA 2014.

Notes: DSI refers to demand side integration; IC refers to grid interconnection.

OFF-GRID RENEWABLE ENERGY: MINI/MICRO GRIDS

Mini-grids are emerging as a key player for cost-effective and reliable electrification of rural areas (Figure 5). The IEA estimates that 36 percent of total investments toward achieving universal access by 2030 will be targeted toward mini-grid efforts, or $4 to 50 billion annually, with the vast majority (over 90 percent) coming from renewable energy generation (IEA 2011).

Mini grids are usually composed of a set of electricity generators and energy storage systems interconnected to a distribution network (Climate Change and Development n.d.). Traditionally, mini grids were powered by diesel generators, but the advent of cheaper renewable energy technologies, among others, has contributed to the deployment of renewable based and hybrid (combination of diesel and renewable) types.

Mini grids have the unique advantage of flexibility and scale and as such can provide electricity to rural areas at a much lower cost than grid extension in certain regions. It is estimated that in Tanzania, the cost of connecting rural areas is around $2,300 per connection while with mini-grid it could cost as much as $1,900 per connection (McKinsey 2015). The two main factors affecting the competitiveness of mini-grid are usually the distance from the grid infrastructure and the load size required (Figure 4.6). The Rocky Mountain Institute (RMI) estimates that mini grids are the least cost option for household consumption—between 2 to 12 kWh per month and at a distance of approximately 4km from the existing grid (RMI, 2017). In addition, mini-grids could be scaled up to meet Tiers 4 and 5, although they typically provide energy for Tiers 2 and 3. This would thus further increase the savings made compared to extending the grid.

Although the majority of mini-grids currently installed are diesel based (mainly due to the low capital cost involved), in recent years, renewable energy based mini-grids have been producing electricity at a very competitive cost—if not cheaper than diesel ones, depending on the fuel price. As such, on average a renewable based mini-grid could cost as much as $0.33 per kWh produced compared to $0.43/kWh for diesel driven mini-grids (Figure 4.7) (APP, 2017). IRENA estimates that by 2035, the cost of electricity generation from a solar PV minigrid will be as low as $0.20/ kWh.

In Sub-Saharan Africa, South, and East Asia, mini grids are rapidly emerging as a viable option for providing energy services, thanks to both technological and institutional innovations and cost reductions (ESMAP and CIF 2016). It is estimated that some 5 million households run on renewables-based mini-grids (usually powered by micro-hydro) worldwide with primary markets in Bangladesh, Cambodia, China, India, Mali, and Morocco (Odarno et al. 2016). In Tanzania, some 180,000 households are

FIGURE 4.5 A growing role for mini grids and renewables

(Opportunities for grid extension, mini grids, and distributed renewable energy systems)

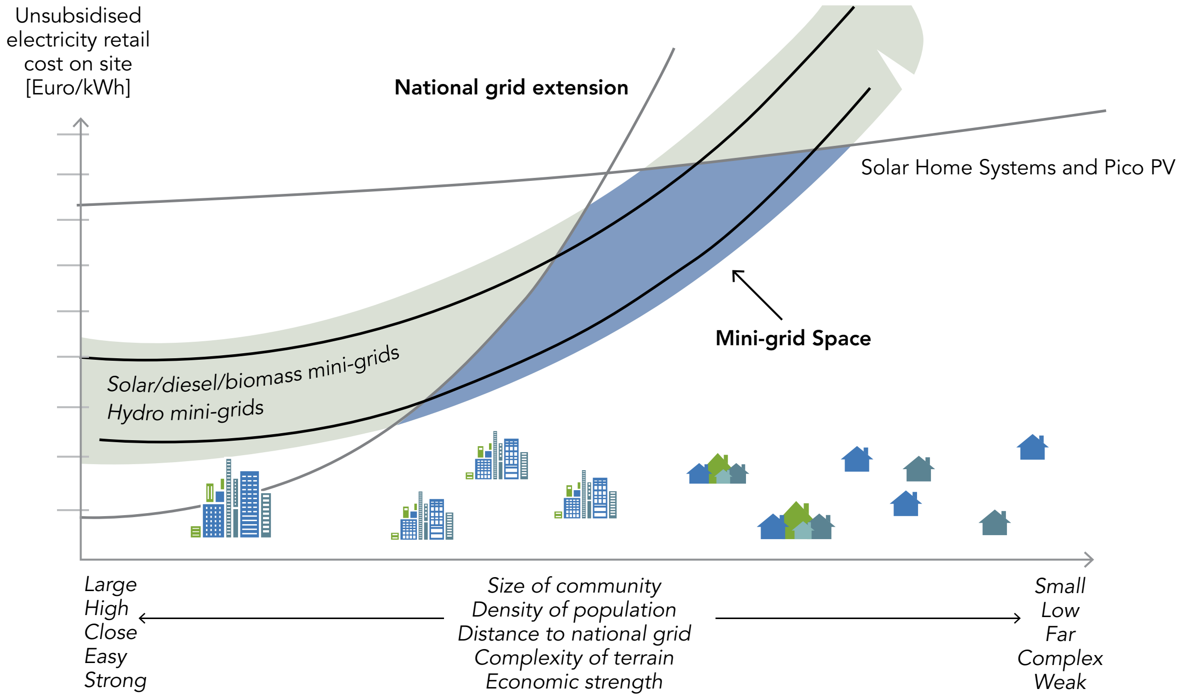
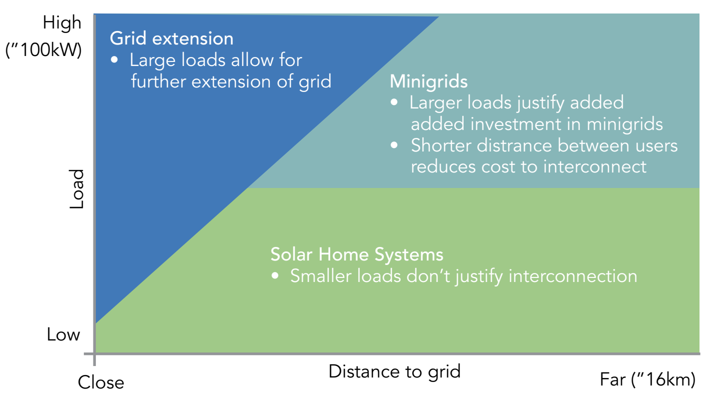


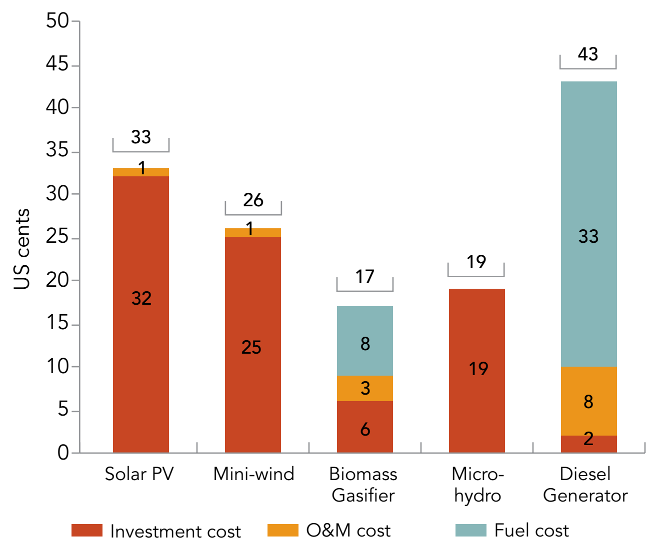
FIGURE 4.6 Least cost option for energy access varies with load size and distance from existing grid



Source: RMI 2017.

FIGURE 4.7 Renewable energy-based mini grids becoming very competitive

(Cost of electricity generated by mini-grids)



Source: APP 2017

being served by 109 mini grid systems, while in Mali about 200 diesel based mini-grids are operating, with a significant number in the process of hybridization (EUEI PDF 2014; Odarno et al. 2016). In the Indian state of Uttar Pradesh, a 250 kW solar mini-grid powering 60 streetlights and 450 buildings (homes, schools, and a healthcare facility) was finished in 2015; another 80 villages operate mini-grids using biogas produced from gasification of biomass residues. India's Jewaharlal Nehru National Solar Mission has announced the installation of a 2,000 MW PV system including pico/mini-grids. And about 50 percent of the Philippines's population can best be served using mini-grids (Siddiqui 2015).

Hybridization of mini-grids is increasingly popular, especially in countries that have been powering their existing mini-grids with diesel. Hybrid mini grids reduce the generation costs of electricity, leading to potential savings and a lower fuel price risk exposure (PWC n.d.). Moreover, an expected decrease in prices of storage/battery systems will increase the use of renewables and reduce the share of diesel. Renewables will thus be used to cover low loads at night, and morning and mid-day loads, with diesel mainly supplying evening peaks (Carbon Tracker Initiative 2014). A recent comparison of diesel and hybridized mini grids at seven sites (three in Africa, two in Asia, and three in Latin America and the Caribbean) shows potential savings range from 12 to 20 percent, depending on oil prices (Al-Hammad et al. 2015).

- In April 2016, Tanzania implemented the first of 30 solar/diesel mini grids to be installed over the next two years, which should serve about 100,000 people (African Review of Business and Technology 2016).
- In the Maldives, its 200 inhabited islands are powered by diesel mini-grids. Some of these are now being converted into solar-PV-diesel mini grids, as part of the government's strategy to transition to a 100 percent renewable energy-based economy.
- In Africa (Mali, Kenya, and Tanzania) and Asia (Bangladesh and Myanmar), various donors and governments are supporting clean energy mini-grids.

Micro and pico-hydro stations (1kW) offer a very affordable source of electricity for many communities. In Indonesia, 20 percent of the country's 51 MW installed capacity is from micro-hydro systems, with about 20 percent of its unelectrified population now having access to cheap electricity.

- In Nepal, 2,600 micro and pico-hydro systems have been installed across the country.
- In the Philippines, there are plans to build 150 to 200 micro-hydropower plants to provide electricity to remote regions, with a goal of increasing hydro generating capacity by 50 MW (Harris 2015).

Mini grids can also contribute to the socio-economic development of a region or community. Besides providing basic energy services (like lighting and charging), they can fuel productive activities (like pumping, milling, and processing (Table 4.1) and provide electricity to community health clinics and schools. India has announced plans to install some 8,960 solar agri-pumps and 500 solar-powered mini grids by 2016 in the state of Maharashtra. The work is being carried out through the state's Smart Power for Rural Development program, financed by the Rockefeller Foundation (Wiemann and Lecoque 2015).

But the huge potential for access of mini grids is hindered by numerous challenges, including inadequate policies and regulations, lack of proven business models for commercial roll-out (notably for pico-solar systems), and lack of access to long-term finance (PWC Global Power & Utilities 2016).

OFF-GRID RENEWABLE ENERGY: STAND-ALONE SYSTEMS

It is estimated that the 1.2 billion people living off the grid in the world spend some $27 billion every year on lighting and mobile phone charging—using kerosene lamps, kerosene generators, candles, and car-batteries that are inefficient and damaging to both human health and the environment as well as being safety hazards. Renewable

TABLE 4.1 Renewables offer a wide range of energy services for productive uses
(Population-based for different rural electrification targets)

ENERGY SERVICES	INCOME-GENERATING VALUE	RENEWABLE ENERGY TECHNOLOGIES
Irrigation	Better crop yields, higher value crops, greater reliability of irrigation systems, enabling of crop growth during periods when market prices are higher	Wind, solar PV, biomass, micro-hydro
Illumination	Reading, extending operating hours	Wind, solar PV, biomass, micro-hydro, geothermal
Grinding, milling, husking	Creation of value-added products from raw agricultural commodities	Wind, solar PV, biomass, micro-hydro
Drying, smoking (preserving with process heat)	Creation of value-added products, preservation of products that enables sale in higher-value markets	Biomass, solar heat, geothermal
Expelling	Production of refined oil from seeds	Biomass, solar heat
Transport	Reaching new markets	Biomass (biodiesel)
TV, radio, computer, internet, telephone	Support of entertainment businesses, education, access to market news, co-ordination with suppliers and distributors	Wind, solar PV, biomass, micro-hydro, geothermal
Battery charging	Wide range of services for end-users (e.g., phone charging business)	Wind, solar PV, biomass, micro-hydro, geothermal
Refrigeration	Selling cooled products, increasing the durability of products	Wind, solar PV, biomass, micro-hydro

FIGURE 4.8 Many types of solar pico PV systems are available

Solar lanterns | **Solar kits** | **Solar home systems**

Solar lanterns are single devices with an associated PV panel to charge them.

From top to bottom:
d.light, Kamworks, Greenlight Planet

Solar kits comprise more than one light offering phone charging, radio or additional lights.

From top to bottom:
Barefoot power, Duron, Sundaya

Solar home systems are a larger PV panel, permanently installed on a roof or pole, with various uses.

From top to bottom:
Tecnosol, SELCO, Sunlabob

Source: IFC

energy technologies (such as solar lamps and charging kits) can offer a reliable, more cost effective, and safe alternative to the tradition methods of lighting. There are many types of solar pico PV systems available—notably solar lanterns, solar kits, and solar home systems (SHS) (Figure 4.8). Solar lanterns, solar mobile phone chargers, and certain SHS can provide Tier 1–3 energy services (as per the Global Tracking Framework Tier Based System) for about 4-20 percent of the cost required for grid extension (Carbon Tracker Initiative 2014b), making them cost effective and quick to implement solutions to the access problem for basic energy services.

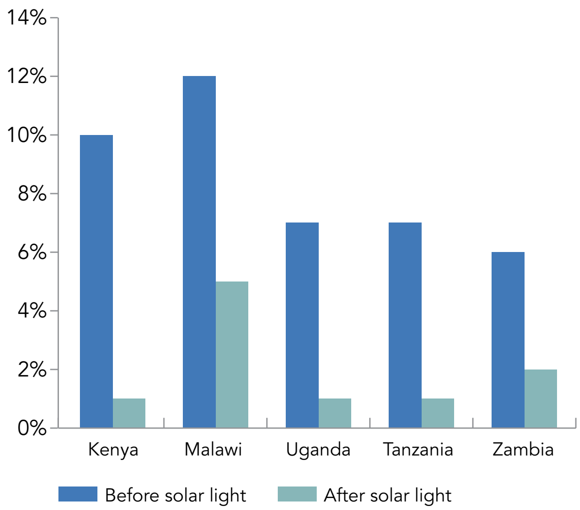
The cost of these systems has gone down in part thanks to the emergence of direct current (DC) end-use appliances, where renewable energy-based off-grid solutions are expanding rapidly. These appliances eliminate the need for inverters and reduce distribution losses, maximizing the use of limited output from small generation units. The increasing adoption of renewable energy off-grid access systems can boost the demand for DC appliances, helping reduce their cost (due to economies of scale-induced market transformation) and opening new markets. With the rapidly decreasing costs of stand-alone/isolated renewable energy systems, coupled with energy efficient appliances, renewable energy is no longer considered an expensive option for access. If in 2009, solar lanterns could cost as much as $45, nowadays with high efficiency LED lamps they can be purchased on average for $10 making it an affordable alternative for lighting and mobile charging. The use of pico-solar systems can help considerably decrease the amount spent on lighting. For instance, Solar Aid, a private solar company, which has sold some 1.5 million solar lights (benefiting some 9 million people), estimates that solar lights can help African families reduce considerably their lighting expenditure (about $140 per year) and save up to 12 percent ($60) of their total income simply by not using kerosene for lighting purposes (Harrison et al. 2016). The BNEF estimates that for every $1 spent on solar lighting, savings of $3.15 could be made, which may help to recover the upfront cost of the latter within four months' time. And ODI estimates that the proportion of household income spent on lighting as a percentage of total income has dropped sharply in Kenya, Malawi, Uganda, Tanzania, and Zambia thanks to solar lighting (Figure 4.9).

In addition to considerably reducing the health hazards linked to the risk of fires and burns of candles and kerosene lamps, solar lighting has proven to help students in their education. In Kenya, Malawi, Tanzania, and Zambia, children are able to increase their study time from 1.7 hours to 3.1 hours with brighter light form solar LED lamps (Africa Progress Panel, 2017).

Solar lighting can be considered as one step up the energy ladder for the off-grid population in Africa, Asia,

FIGURE 4.9 Many African households spend a lot less of total income due to solar lighting

(Proportion of household income spending on lighting as a percentage of total income in selected African countries)



Source: Overseas Development Institute 2016; Africa Progress Panel 2017

and Latin America, since it offers both the opportunity to make savings to purchase other electrical appliances (television, radios, fans, and refrigerators) and the basis to upgrade toward larger systems such as solar home systems. The cost of solar home systems together with a television a radio and two LED lights is around $350, down from about $1,000 five years ago (ODI, 2016).

Pico solar PV systems typically provide less than 10 watts of power and are primarily used for lighting or powering electrical appliances (like radios or mobile phones (REN21 2016). They have developed rapidly in recent years, due to the less costly solar modules, the use of highly efficient LED lighting systems, and the emergence of innovative business models.

By mid-2015, about 44 million off-grid pico-solar products were sold globally—representing a market of $300 million annually—and by end-2015, about 70 countries had some off-grid solar capacity installed, or programs in place, to support off-grid solar applications. The largest market for off-grid solar products is sub-Saharan Africa (1.37 million units sold; Kenya and Tanzania are the leaders), followed by South Asia (1.28 million units sold; India is the leader) (Bloomberg New Energy Finance 2016).

Solar lighting systems (solar lanterns) have seen the greatest development in recent years—and they are now considerably cheaper than conventional kerosene-based lighting systems (depending on existing subsidies). Solar lanterns, often priced as low as $10, provided lighting to 28.5 million people across the African continent by end-2014: in Kenya, these lanterns provided lighting to about 12 percent of the population, and in Tanzania's Lake region, about 50 percent of the population (Global Off-Grid Lighting Association 2015; Solar Aid 2015). India is the market leader for solar lighting systems, with just under one million solar lanterns installed in the country by end-2014.

SHS have also gained in popularity, with systems ranging from pico-systems (1-10 W) to larger systems (up to 250 W). Pico systems are best suited for lighting and providing electricity to run mobile communications devices and radios, while larger systems are used to power health centers, schools, and households. The largest market for SHS is Bangladesh where, by 2015, an estimated 6 million SHS and kits had been installed, with 60,000 new households being connected to SHS every month (Rahaman 2015). The market is also quite active in other Asian countries—namely India, China and Nepal, which together account for 2 million installed systems (Ministry of Statistics and Programme Implementation 2015). The African market is concentrated in East Africa. M-Kopa, an SHS company, has installed about 300,000 SHS in Kenya, Uganda, and Tanzania (M-KOPA 2016).

Solar kits are now an affordable alternative to SHS. In fact, they are the portable version of a SHS that does not need any significant installation or regular maintenance. These systems often sell for half the price of a traditional SHS and can power multiple lights, charging devices, and small electrical appliances.

Coupled with the explosive growth of companies selling solar pico PV systems across Asia and Africa, is the level of investment in off-grid companies. Investment has increased considerably in recent years, reaching $276 million in 2015 (Figure 4.10) (REN21 2016). The cumulative investment total since 2011 is $511 million (BNEF 2016).

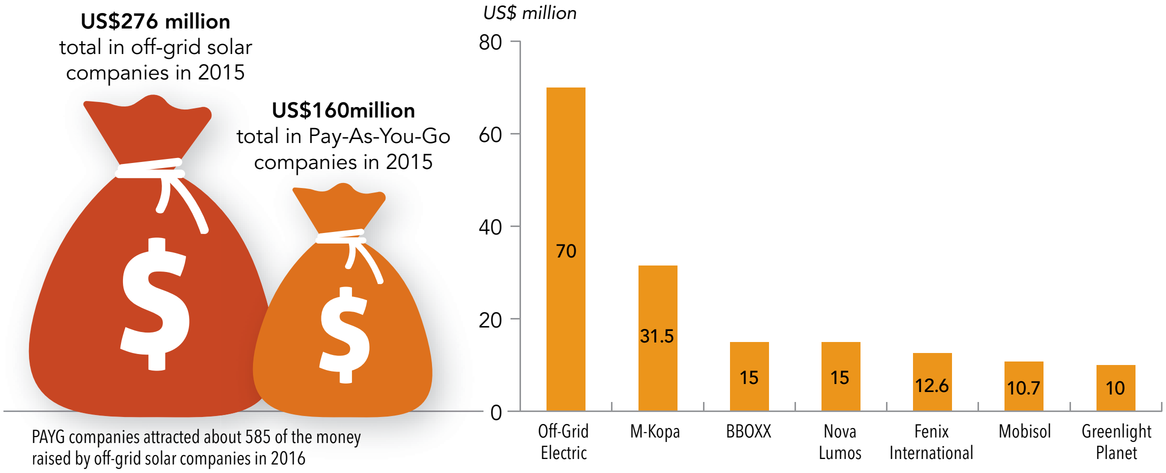
CHALLENGES AND SCALING-UP OPTIONS

So what are the biggest obstacles that countries face in introducing and scaling-up the share of renewables in energy use? Keep in mind that clean energy projects are characterized by high initial investment costs and substantial risks. The obstacles range from high fossil fuel subsidies and the inadequate communication of the advantages of renewables to unclear government policies, a lack of good financial options, and not enough community involvement. Thus, possible solutions include the following:

Phase out fossil fuel subsidies. The problem is that these subsidies distort the true costs of energy and encourage wasteful spending and increased emissions. They also present a barrier to scaling up clean energy by: (i) decreasing the costs of fossil fuel-powered electricity generation, thereby blunting the cost competitiveness of renewables; (ii) creating an incumbent advantage that strengthens the position of fossil fuels in the electricity system; and (iii) creating conditions that favor investments in fossil fuel-based technologies over renewables. Fossil fuel subsidies were estimated to be over $490 billion in 2014, compared with subsidies of only $135 billion for renewables (IEA n.d.). Policy design should financially discourage investments in fossil fuels and nuclear, while also removing risk from investments in renewable energy. This is crucial for scaling up renewables, which can help close the energy access gap (REN21 2016).

FIGURE 4.10 Increasing amounts of money being invested in off-grid companies

(Capital raised by off-grid companies in 2015 and share of Pay as You Go (PAYG) companies)



Source: REN21/BNEF

Better communicate advantages of renewables. Renewables are still less known and often suffer from a lack of understanding about the full cost of a renewable systems, benefits, opportunities, and capabilities—thereby acting as a barrier to effective deployment of large shares of renewables into the grid (Bridle et al. 2013).

Provide greater consistency in energy policy planning. Renewable energy policy changes and uncertainties undermine investor confidence, inhibiting investment and deployment in some markets. Investors consider all of these factors in their decision making, as do insurers (demonstrated by the increasing presence of insurance addressing climate change risks). Likewise, policy makers should think on a long-term basis in order to increase investment in clean energy and advance the energy transition in their countries.

Improve financial options. Public finance mechanisms are needed to leverage private sector investment, overcome a lack of private financial instruments, facilitate high-capacity deployment, and mitigate risks. For example, they would be especially critical for deploying stand-alone systems, which are often constrained by a lack of available financial resources, high up-front technology costs (including the cost of connections), and reluctance by investors and decision makers. This problem is further exacerbated because the majority of people that lack energy access have limited financial means to pay for energy services (5P and GIFT 2014). Thus, the success of rural electrification requires the use of a customised and financially sustainable business model (PWC Global Power & Utilities. 2016).

Since the 1990's, innovative business models, often developed in collaboration with private industry, have opened up the off-grid market. Early models included micro-credit and fee for service. Innovative business models—such as the pay-as-you-go (PAYG) model or the one-stop-shop model—are now emerging as leading models and leading off-grid access developments.

Create a clear, stable, and transparent legal framework. If governments want to attract more private capital, they will need to establish not only financing mechanisms but also agreements through which the purchase of the power generated is guaranteed for a long period of time and at an agreed price. Also, publicly shared and stable electrification plans are fundamental.

Promote community participation and ownership. This is vital for off-grid electrification programs in particular. An underlying principle is that the renewable technology is not free-of-charge or unreasonably subsidized. Financial support of renewable energy projects by communities allows residents/owners to decide what technology to apply (such as solar PV, wind, or biomass) and how resultant energy services are used; they are not passive consumers, but active participants and might even be energy producers. That said, contributions do not have to financial—communities and households can donate time (digging a canal), land (donating land for the project site), or resources (wood for distribution poles). As the World Bank has noted, "participation of local communities, investors, and consumers in the design and delivery of energy services is essential".

Build local capacity. This is key to create self-sustaining renewable energy markets for off-grid electrification, which do not depend on external support or international actors. Selecting partners that already have networks in rural areas and building the technical or managerial capacity of domestic companies and institutions is key.

Catalyze high-level support. High-ranking ministerial or cabinet offices need to help promote the scaling-up of renewables for access. This means raising awareness about renewable energy solutions for increasing access, providing training for current and future decision makers, and developing a "marketing strategy" by providing good data, organizing market players, and outlining the driving forces that shape policy decisions.

ENERGY EFFICIENCY

Once overlooked, energy efficiency is being seen increasingly as a key tool in delivering modern and clean energy services. Energy efficiency offers the unique opportunity of enhancing the deployment of clean energy and pursuing energy access objectives. By end-2015, at least 146 countries had enacted energy efficiency policies, while at least 128 countries had energy efficiency targets. There has also been a drop of more than 30 percent in the primary energy intensity between 1990 and 2014 (REN21 2016).
The attractiveness of energy efficiency are many:

- It reduces peak loads, lowering the level of investment required to meet high-energy demand at peak hours. This reduction in demand allows more people to be supplied with energy services with the same power production capacity.
- It lowers energy costs, providing households with the option to spend less on energy services or move up the energy ladder.
- It reduces government expenditure on fossil fuels.
- It prevents the long-run lock-in of inefficient products and appliances that may hamper the success of clean energy and energy access initiatives (Pachauri et al. 2012).

Whether access is grid-connected or off-grid, energy efficiency offers a two-fold opportunity for improving delivery. By increasing the efficiency of production, transmission, and distribution processes, it frees up energy resources, thus acting as a "virtual power supply" (IEA 2015b). From the demand side, energy efficient appliances can accelerate the diffusion of modern energy services (Table 4.2).

Moreover, from 2010–2015 the World Bank lent over $5.2 billion for energy efficiency projects that brought substantial additional benefits, ranging from improved electricity transmission capacity to higher industrial productivity and lower energy poverty.

By reducing the size of the energy supply infrastructure needed to provide a given level of energy services, energy efficiency mitigates the costs and the negative social and environmental impacts from the energy supply. The benefits of energy efficiency are well documented in industrialized economies and experience suggests that efficiency can be a first-order energy access resource. Wherever new energy supplies are needed, energy efficiency—both supply and demand—can reduce the amount of investment needed. Wherever existing supplies fall short or are unduly expensive, energy efficiency can improve system reliability and performance, and reduce energy costs.

TABLE 4.2 Energy access interventions and indicative energy efficiency benefits

The EA+EE Opportunity in Context

ACCESS TIER	TECHNOLOGY OR MODE OF DELIVERY	ENERGY EFFICIENCY'S VALUE PROPOSITION
TIER 1	Solar Portable Lanterns / Pico PV	Energy-efficient light emitting diodes (LEDs) radically reduce the size and costs of the solar PV and batteries needed to provide service, making these technologies affordable for vast new market segments.
TIER 2,3,4	Off-Grid Systems	Energy-efficient appliances radically reduce energy supply needs, allowing a given off-grid system size to provide greater service and smaller, more affordable systems to provide equivalent service.
	Micro- and Mini-Grids	Energy-efficient appliances and devices can increase the number of connections a mini-grid can support, and can reduce a system's capital cost requirements, potentially improving financial viability.
	Industrious / Community Uses	Energy efficiency reduces the energy costs and/or extends the run time of motorized products such as mills, grinders, and pumps. Efficient solar LED street lights increase public safety and facilitate after dark commerce. Efficient solar pumping systems for irrigation have been found more cost effective than the average electric pumps. Efficient medical applications operate more reliably in under-electrified rural clinics, or require smaller and more affordable off-grid energy systems.
TIER 5	Grid Electrification / Power Sector Reform	Supply- and demand-side efficiency improvements can enhance power sector reliability and financial performance; lowering prices for consumers, and increasing likelihood of energy bills being paid. In sectors with subsidized tariffs, efficiency can lower government costs.

Note: SE4All has developed a multi-tier framework for global tracking of energy access. Tier 1 represents very low energy service and Tier 5 includes full grid connectivity with higher power appliances.

Energy efficiency options for access can complement renewable energy as they permit greater levels of services for the same power levels. Possible options include LED lighting to replace incandescent and fluorescent lamps, high-efficiency appliances such as TVs and fans, high-efficiency motors for community scale industry and agricultural processing, and improved pumps—ideally paired with processes like drip irrigation that minimize water use. These options typically have higher initial costs, but these costs are offset by the lower costs of the smaller power supply system (such as cheaper replacement items like batteries).

Efficiency on the Supply Side

On the supply side, the incentive structure—utilities and other grid-connected energy service providers typically earn revenue for each unit of energy sold (such as kilowatt hours)—favors energy consumption and discourages energy efficiency, despite the latter's importance in the energy service business model.

As a background, paper for this report on energy efficiency puts it: "Large-scale deployment of highly efficient end-use products reduces peak demand, which in turn mitigates load shedding and the need for large new generating supply investments. Reduction in peak demand can reduce the need for spot generation and energy/fuel imports, which can be prohibitively expensive and can complicate sector and utility financial planning. Wide scale energy efficiency can also improve service and customer satisfaction, which, when coupled with the lower energy bills, improve customer payment. Supply-side efficiency gains—like grid rehabilitation in Brazil, China, India, Mexico, and Vietnam (Box 4.2)—can enhance system reliability, improve financial performance, and ensure that megawatts generated are megawatts sold—all of which improve the availability and reliability of energy service in an energy constrained context"(Jordan et al. n.d.).

Although the current world average for the electric power transmission and distribution losses is estimated at 8 percent the amount tends varies widely across countries and regions. While the OECD average is about 6-7 percent, the average for the sub Saharan African region is around 12 percent, compared to 15 percent for Latin America and the Caribbean, and 18 percent for South Asia. Similarly, in Africa while countries like Mauritius, South Africa, or Zambia enjoy electric power losses of less than 10 percent, others like Togo, Benin and Congo, have a high rate of power losses—87 percent, 61 percent, and 44 percent, respectively.

These losses mainly stem from technical losses, caused by inefficient equipment and poor maintenance, and non-technical loses, usually attributed to theft and the underpricing of electricity. The result is an unstable, sub-optimal, power system that hurts end-users, often impeding the ability of firms to operate efficiently. It also can undercut economic and social development—by lowering enterprise productivity, employment, and competitiveness, and creating significant constraints on economic activity and growth.

Thus, increasing the efficiency of power transmission and distribution infrastructure is a key issue that needs to be addressed. It is often linked to the poor financial performance of utility companies, which limits the ability of countries to improve the efficiency of the electricity infrastructure. In many African countries, the high rate of grid loss and poor transmission and distribution networks has only allowed for the electrification of urban areas only. Moreover, the loss in power supply could have been utilized to provide energy access to millions without any significant investment in new power capacity (KPMG 2015).

BOX 4.2

Renewable Technologies Come in Various Shapes and Sizes

At utility scale, they provide electricity to meet the diverse needs of grid-connected urban and rural customers. Grid-connected clean energy technologies can range from a few kilowatts of roof top solar photovoltaics (PV) systems connected to the low voltage distribution network, to 10 to 1,000s of megawatts of large centralized utility scale power plants. Examples include hydropower, solar parks, wind farms, geothermal power plants, or biomass-fueled plants connected to medium and high voltage substations. These utility scale renewable energy plants are in place in Ethiopia, Kenya, Rwanda, and elsewhere, providing better quality service to existing customers, as well as widening the reach of the grid to those previously without access.

In *mini-grid configurations,* clean energy technologies can meet the needs of communities sooner than waiting for grid extension. A clean energy technology mini-grid can be a single power source—such as a small hydropower plant, or a hybrid system with renewable energy sources with batteries or a diesel generator. In the Indonesian archipelago, many of the 6,000 inhabited islands are powered by diesel- or small hydro-mini-grids; recently some are being retrofitted with solar PV systems to avoid high cost diesel fuel.

When communities are small or dispersed and electricity demand is limited, ***stand-alone systems***—such as ***solar home systems (SHS)***—can be more cost effective, especially when coupled with new business and financial models. Increasingly, small PV systems, known as pico-solar systems (ranging from a few watts to tens of watts of solar PV) provide high value lighting and mobile phone services.

Source: SEAR Special Feature Paper on Energy Access: Food and Agriculture (Dubois et al. 2017)

Many countries have embarked on, or plan to undertake, a grid loss reduction program that complements both their energy access objective and their transition toward renewable energy—although large-scale loss-reduction schemes may be expensive and hence difficult to finance by poorly performing utilities. Sierra Leone, as per its SE4ALL Action Agenda, plans to reduce its grid losses from 17 percent currently to 9 percent by 2020 by upgrading its grid infrastructure, investing in low voltage distribution, and improving the monitoring of customer consumption to avoid non-technical losses (ECREEE 2015). India, with a transmission and distribution loss of 23 percent, is increasing its efforts to reduce grid losses—in part through a planned mandatory labelling of distribution transformers (Mohan 2014). Rwanda, in line with its SE4ALL objectives, secured financing of $25 million in 2015 from the European Union to improve and upgrade its grid infrastructure to reduce its power loss from 23 percent to 17 percent in the coming years (Bateta 2015).

Energy Efficiency on the Demand Side

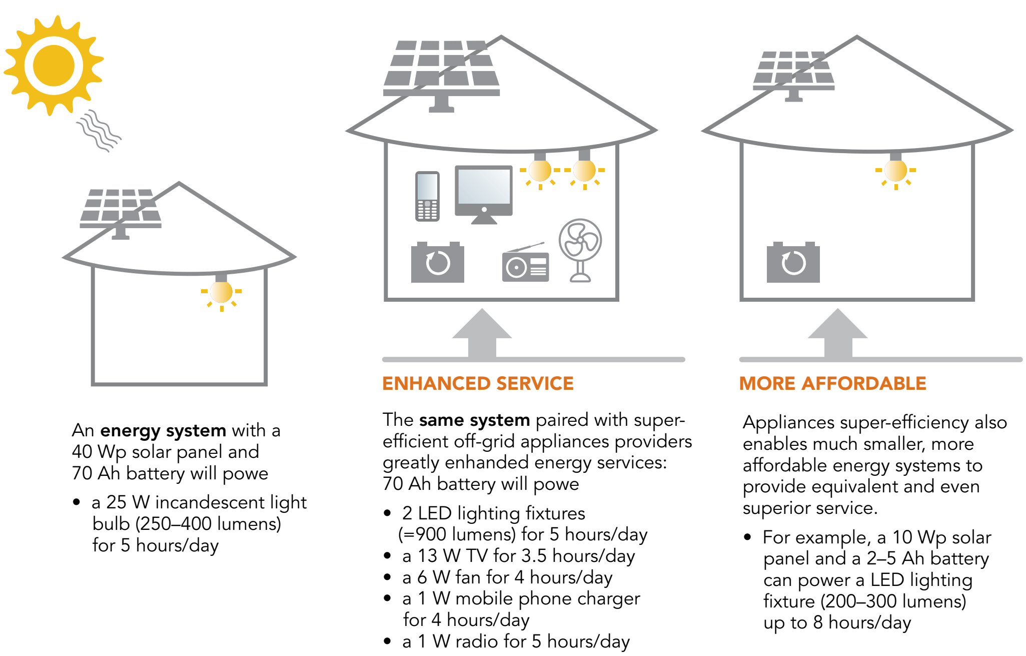
The success of off-grid technologies for providing energy access in recent years is largely attributable to the availability of energy efficient appliances. For instance, in many countries the use of high efficient LED lamps has enabled the implementation of various modern lighting programmes and initiatives in rural and electrified areas. As the Royal Swedish Academy of Sciences put it when announcing the 2014 Nobel Prize in Physics: "The LED lamp holds great promise for increasing the quality of life for over 1.5 billion people around the world who lack access to electricity grids. Due to low power requirements, it can be powered by cheap local solar power."

Energy efficient appliances have helped to reduce the energy investment costs required to kick-start energy access programs. Shaving a single watt from an off-grid appliance's load results in lower initial solar package costs, improved service, or both (Van Buskirk 2015). Similarly, energy efficiency can make larger off-grid solar home systems more affordable (Figure 4.11). According to a recent analysis "the upfront cost of a typical off-grid energy system can be reduced by as much as 50 percent if super-efficient appliances and right-sized solar PV and batteries are used, while delivering equivalent or greater energy service." (Van Buskirk 2015).

Thus, advances in energy-efficient devices — including DC appliances as mentioned earlier — now allow households to reap more benefits and at a lower cost from the relatively small amounts of electricity available to them. Instead of illuminating a single light bulb, CFLs and LED lamps use provide more and better light and consumer less energy, leaving enough energy to power other electronic devices such as fans and low-wattage TVs and appliances, as Figure 4.12 shows.

Moreover, the positive impacts of efficient lighting on off-grid energy service markets need not remain limited to lighting. The price and service impacts can be replicated for other, more advanced, forms of energy service—such as refrigeration, telecommunications, and industrial appliances. Off-grid solar LED street lighting provides communal lighting and promotes public safety and after-dark social and commercial activity. Similar to solar home systems, the use of efficient LEDs reduces the need for more expensive solar PV and battery configurations. Municipal street lighting can account for 20 percent or more of a city's grid-connected electric load. Retrofitting street lights with

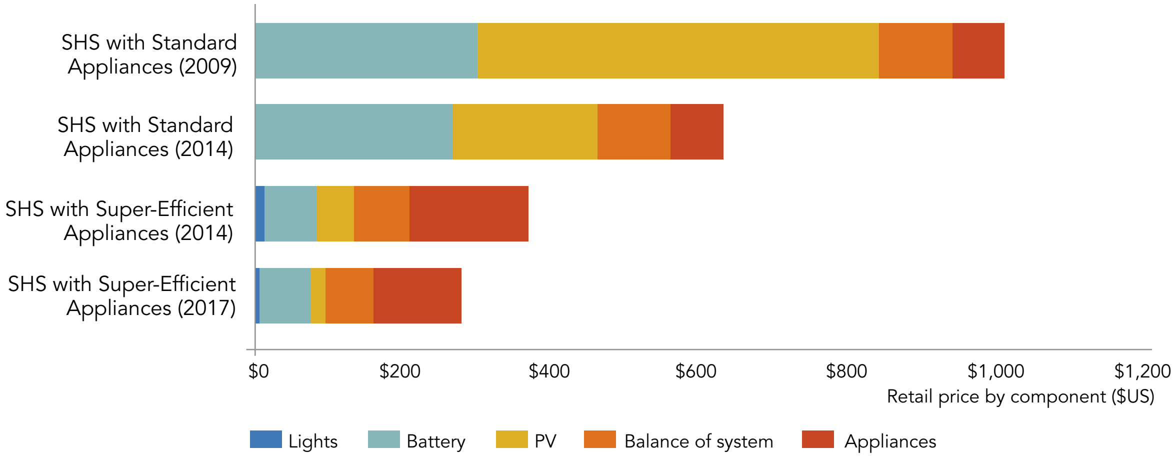
FIGURE 4.11 Linking energy efficient appliances and energy access through clean energy



Source: Global LEAP Initiative. Analysis courtesy of Humboldt State University's Schatz Energy Research Center.

FIGURE 4.12 Solar home systems increasingly offer more for less

(Retail purchase price for three solar home systems that provide identical levels of service)



Source: PHADKE 2015.

LEDs can achieve significant energy savings — reducing energy supply constraints, freeing up energy for other uses, and potentially improving grid reliability (Silverspring Networks n.d.). In Guadalajara, Mexico, energy savings from retrofitting streetlights with LEDs has led to over 50 percent reduction in energy consumption (Makumbe et al. 2016).

With the rapid development of the off-grid energy sector, the untapped market of direct current (DC) energy efficient appliances has received renewed interest. Under the traditional grid-connected model, alternating current (AC) power has become the norm. However, given that solar PV produce and batteries store DC power, it might be more economical to use DC appliances. With DC appliances connected to off-grid energy systems, there is no need for conversion between AC and DC. There is thus no need for an inverter for the off-grid system as well as a significant decrease in electricity losses. In addition, with the efficiency gain from the use of DC appliances, the size of PV panels needed for a SHS and battery systems is considerably reduced, resulting in a decline in the cost of off-grid energy systems and dramatically increasing their affordability. The availability of DC appliances (namely DC television, radio, fans, and refrigerators) could in the long run prove to be a major driver for the off-grid solar market. Already in 2015, more than 137,000 SHS together with DC appliances have been sold in East African countries (GOGLA 2016).

Linking Up Energy Efficiency and Access

What can be done to better link up energy efficiency and access, given how important they are to each other? Off-grid energy access companies around the world are creating a global market to reach billions of consumers—and energy efficiency underpins their success in meeting these needs. Conversely, energy access markets hold the potential to drive energy efficiency technology, market, and policy to leapfrog longstanding challenges associated with energy efficiency, unlocking untold economic and environmental benefits, and transforming the way the world consumes energy.

Certainly, the global off-grid marketplace will need a complementary, competitive marketplace of low-cost, energy-efficient, high quality, and well-designed off-grid appliances. At this point, such a market does not exist, due largely to a lack of familiarity with the off-grid market opportunity by appliance manufacturers, as well as the risks and difficulties of market entry perceived by those manufacturers. Moreover, off-grid companies are ill-equipped to develop off-grid appropriate appliances of their own, and the market infrastructure to equip off-grid companies to source outstanding appliances is lacking. Against this backdrop, five key challenges stand out:

Lowering tariff barriers. Developing countries often impose high import duties on appliances and equipment, usually to protect domestic manufacturing, generate revenue, or generate income from perceived luxury items (like a "luxury tax"). Reducing duties for high-quality, highly-efficient products—possibly benchmarked against an international or regional standard—will lower downstream prices for these products and make them cost-competitive with inefficient products, in turn, spurring uptake and access to benefits (such as lower costs and reduced load shedding).

Easing financial constraints. The procurement processes tend to favor products with the lowest initial price, despite the fact that although many products with superior energy performance have a higher up-front cost, they have a significantly lower life-cycle cost.

Encouraging political and market champions. Economies with energy access challenges often need a strong and vocal community of efficiency stakeholders. A major barrier is that frequently there is little overlap between the professional communities who work on energy efficiency and energy access; energy access experts are not necessarily energy efficiency experts, and vice versa.

Enhancing visibility. It is tempting, and politically convenient, to just add more generation capacity. But the focus needs to be on improving energy efficiency to bolster energy service and sector performance—which will have a longer time horizon, even though it is less visible and harder to quantify.

Creating self-sustaining markets. This is a major challenge given that it requires a level of infrastructure that is often lacking in countries with low levels of access. But it is vital for ensuring quality, not to mention enforcing standards.

The good news is that despite these challenges, and a general lack of priority on energy efficiency efforts, there are many examples of smart practices and effective models for incorporating energy efficiency in access activities. In recent years, a slate of high-impact programs have prioritized a broader view on developing energy access markets, looking at commercial investment and supply-chain management, to policy reform, to consumer awareness. Common to these efforts are:

- A thoughtful evaluation of their respective markets' fundamentals and barriers.
- A nimble market-based approach to improving those fundamentals and removing those barriers.
- An appreciation of the importance of product quality and energy efficiency to sustainable market growth.

The new programs—such as Global LEAP (the Global Lighting and Energy Access Partnership)—will encourage the development, marketing, and quick uptake of energy efficient, off-grid appliances.

THE CO-BENEFITS OF CLEAN ENERGY

Historically, the reasons for investing in clean energy were to increase security of supply, reduce greenhouse gas (GHG) emissions, and provide off-grid access to electricity. Investment occurred despite the fact that electricity from renewable resources was often more expensive than conventional generation, especially when technology costs were still high.

Today, the rationale for investing in clean energy tends also includes its "co-benefits"—that is, the positive side effects, secondary benefits, collateral benefits, or associated benefits from a particular green policy or clean energy system (Miyatsuka and Zusman 2010). These benefits can be direct or indirect, as well as monetary or non-monetary, although challenges remain in quantifying them.

Lower emissions and costs. Clean energy promotes availability, affordability, technology development, sustainability, and regulation (Sovacool 2011). Typically, an "optimized" level of diversification is achieved when different types of clean energy are promoted at once, or certain portfolios of energy systems are arranged to explicitly minimize risk across the entire sector at the lowest cost. Many renewable electricity systems can provide hedging against fossil fuel price volatility and reduce GHG emissions to improve stakeholder relations and revitalize rural areas (Pater 2006), while energy efficiency can contribute to energy security and enhance the reliability of supply, particularly in capacity-constrained systems. For instance, energy efficiency measures in IEA member countries avoided at least 190 Mtoe of primary energy imports in 2014, equivalent to $80 billion (IEA 2015b). The shift to clean energy also forces a move away from existing, often inefficient infrastructural systems, often resulting in improved energy security. The use of efficient appliances in low income households can have a significant impact by reducing energy bills, and thus freeing up disposable income. It can also keep these households within the consumption blocks for which tariffs are lower (e.g. social tariffs) (Sarkar and Subbiah, 2013).

A more sustainable clean energy market. Linking off-grid energy systems with energy efficiency creates a virtuous circle for the clean energy market. As Figure 4.13 illustrates, energy efficient off-grid appliances considerably reduce the price of off-grid energy systems needed to power them, thereby increasing the demand for the latter. The savings made by households through the use of renewable energy off-grid systems allow households to move up the energy ladder, thereby increasing the demand for energy efficient appliances. As a result of economies of scale, the price of those appliances decreases, making off-grid energy more affordable.

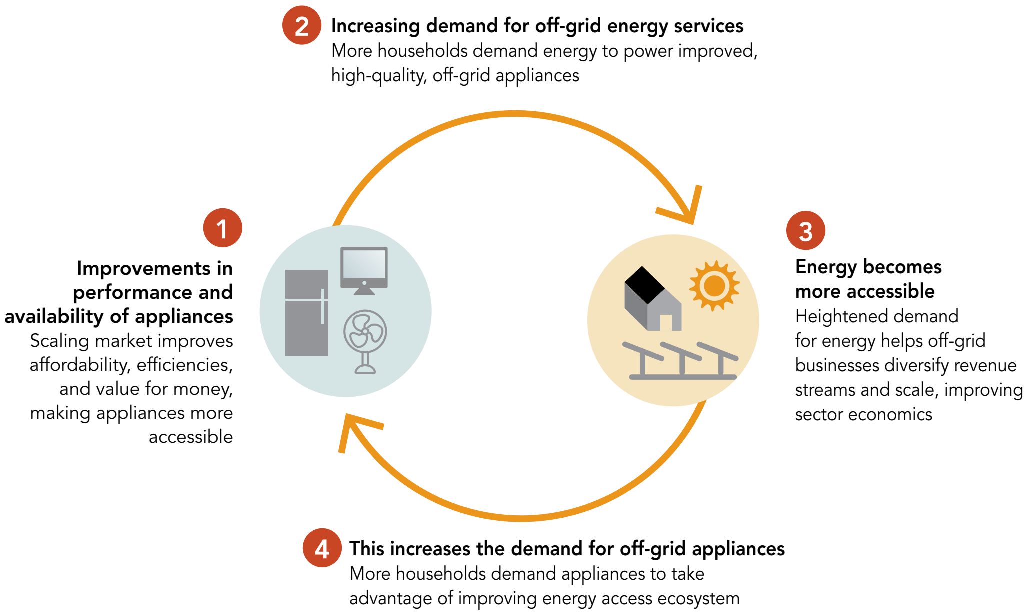
More jobs and higher green growth. The more capital intensive an energy technology or infrastructural system is, the less embodied labor it has. That is why nuclear power and fossil-derived electricity, which are the very capital intense, cause net reductions in regional employment—ratepayers have to lower expenditures on other goods and services to finance construction. In contrast, renewable energy, which is much less capital intensive, creates jobs.

In 2015, global gross employment in this sector rose by an estimated 5 percent, reaching 8.1 million jobs (direct and indirect), with solar accounting for about half of them (Figure 4.14). The bulk of these jobs were in countries that are major equipment manufacturers and producers of bioenergy feedstock (such as China, the United States, Brazil, India, and Germany) (REN21 2016). The jobs cover a wide range of occupations across the value chain—especially, in manufacturing, construction and installations (MCI), and operations and maintenance (O&M)—with big variations in terms of job creation locally and in duration. For example, construction and installation created the most jobs, and wind offshore jobs lasted the longest (Figure 4.15).

Looking ahead, a recent study by IRENA (2016), estimates that global GDP would rise by 1.1 percent if the international community can meet the SE4All objective of doubling the share of renewable energy in the energy mix by 2030—thereby improving human well-being and welfare and contributing to the creation of some 16 million additional jobs in the renewable energy sector (both direct and indirect) (Ferroukhi et al. 2016).

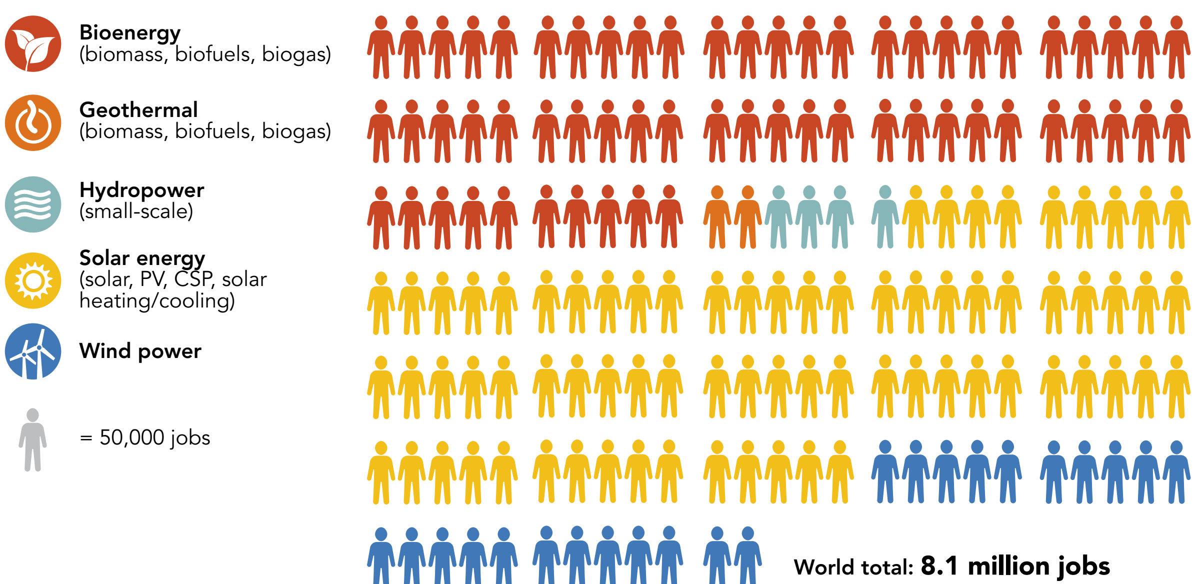
Similarly, in terms of net effect—that is, jobs created in the renewable and energy efficiency sector less jobs displaced in the fossil fuel industry due to investment in clean energy—it is estimated that in the short term in the European Union, 1 job may be created per GWh of electricity

FIGURE 4.13 Virtuous circle for clean energy markets



Source: Global LEAP—The State of Global Off-grid Appliance Market, 2016

FIGURE 4.14 Solar and bioenergy create the most jobs
(Jobs in renewable energy sector, 2015)



Source: IRENA.

saved or generated from clean energy sources (Blyth et al. 2014). India recently estimated that between 2011 and 2014, some 24,000 full-time employment (FTE) jobs were generated in the solar PV industry. If it is to achieve its 2022 target of 100 GW of solar, 1 million FTE may be created in the sector, highlighting the need to build local capacities, skills, and expertise in renewables (NRDC 2015).

Investments in energy efficiency generate opportunities in industries that are more labor intensive by producing more net jobs per dollar invested (ACEEE 2011). The IEA calculates that the 15 percent reduction in energy consumption from 1995 to 2010 added 770,000 additional jobs—equivalent to a 0.44 percent increase in the overall employment rate, and $14 billion in additional annual wages and salary incomes (Geller and Attali 2005).

Fewer climate change impacts, greater resilience, and adaptive capacity. Reducing the energy intensity of agri-

FIGURE 4.15 Some renewable technologies create more jobs than others
(Employment factors by renewable energy technology)

	CONSTRUCTION TIMES	CONSTRUCTION + INSTALLATION	MANUFACTURING	OPERATION + MAINTENANCE	FUEL SUPPLY
	Years	Job years/ MW	Job years/ MW	Jobs/ MW	Jobs/ PJ
Hydropower	2	6	1.5	0.1	
Wind onshore	2	2.5	6.1	0.2	
Wind offshore	4	7.1	10.7	0.2	
Solar PV	1	9	11	0.2	
Geothermal	2	6.8	3.9	0.4	
Solar thermal	2	5.3	4	0.4	
Ocean	3	9	1	0.3	
Geothermal—heat		6.9			
Solar—heat		7.4			
Biomass	2	14	2.9	1.5	32.2
Biomass CHP		15.5	2.9	1.5	32.3

Source: IRENA.
Note: MW stands for megawatt.

culture through better irrigation and reduced fertilization can also create farming techniques that are more drought resilient (Economist. 2011). Increasing the efficiency of space cooling and heating can reduce electricity consumption, while also making cooling more affordable for lower-income groups (Sovacool and Brown 2009). Decreasing exploration and drilling for fossil fuels can prevent GHG emissions from combustion, while diminishing the risk of oil spills and consequent stress on ecosystems (adaptation) (Moser 2012). Energy efficiency programs can reduce energy use and cut consumers' energy bills, translating into greater financial resilience to future shocks (Moser 2012)

CONCLUSION

The continued growth of renewable energy and energy efficiency—despite the tumbling prices of fossil fuels—is a clear indication that there is a global shift toward the adoption of clean energy. Countries are rapidly developing their clean energy strategy, as illustrated by the number of SE4ALL Actions Plans developed and the commitments made in their respective INDC's. This stems from the increasing need to both tackle the issues of climate change and energy poverty, especially in developing countries.

It is clear that clean energy will thus play a very strong role in ensuring universal access to energy services. As costs continue to come down rapidly, system innovations occur, and financiers become ever more comfortable with the asset class, renewable energy and energy efficiency measures will contribute to providing energy access to more than 1 billion people currently lacking basic energy services. Recent developments have dramatically altered the costs, the risk profiles, and the dynamics of investing in the renewable energy technologies, which are increasingly becoming attractive business propositions for the private sector, governments, and consumers.

Off-grid energy has instilled a new dynamic in energy access and is proving to promote incremental shifts up the energy ladder. Renewable based off-grid technologies—solar lighting products, SHS, and mini-grids—are no more considered as interim measures but rather a viable option that has the ability to provide energy services across the full range of energy access suiting the needs and income of households.

Substantial drops in equipment and component prices, enhanced grid integration protocols, innovative off-grid business models, improvements in storage technologies, and other developments are changing the energy landscape—with renewable energy emerging as an increasingly important contributor in both on-grid and off-grid power generation investments.

In addition to addressing the twin challenges of providing modern energy services and mitigating climate change, clean energy may also bring significant co-benefits—including emission reductions, cost savings, more jobs, better health, and a lower risk of climate change.

Providing universal access for all involves a complete rethink of how energy is generated and used. Renewable energy and energy efficiency offer the perfect medium for this rethinking and re-design of our energy system process—essential for igniting the necessary innovations and the required environment to tackle energy poverty.

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CHAPTER 5

EMERGING AND INNOVATIVE BUSINESS AND DELIVERY MODELS

KEY MESSAGES

- The need to balance return-on-investment with customer affordability is increasingly recognized by emerging energy service delivery mechanisms. Public sector support is often necessary to offset upfront private investment costs in capital-intensive renewable energy technology and to attract the finance required for universal access to modern energy services.
- Emphasis on appropriate policy measures is an essential requirement for continued innovation and scale-up—enabling a clear framework for regulation and legislation that facilitates the providers of effective and sustainable delivery models. Lack of policy creates too much uncertainty and, therefore, risk that deters private investors.
- Clear grid expansion plans must be available to suppliers of alternative off-grid options in order to effectively integrate the roles of grid and off-grid solutions. Provisions and processes are also necessary for the circumstances where the national grid is extended to areas that have previously been provided with off-grid connections.
- Training for local service providers is essential to build long-term supply and support structures, but also to allow delivery mechanisms for energy service to be effectively adapted to the unique local conditions. Such capacity building will also contribute to local job creation, economic uplifting, and consequently indirect market creation.
- Emerging and innovative energy service delivery mechanisms are encouraging. If countries could create the necessary environment for them to be replicated and scaled up, countries could accelerate efforts to achieve universal access to modern energy services.

INTRODUCTION

What are the emerging and innovative business and delivery models? A major focus of the international effort to ensure universal access to electricity these days is reaching people living in remote areas in developing countries, but it is increasingly clear that the traditional approach to electricity grid extension will not suffice. The typical utility-based, centralized approach to grid extension involves significant upfront investment in infrastructure to deliver the power required by customers, whose level of consumption will provide a payback for the utility over an acceptable timeframe. But the connection costs to remote areas—which demand less electricity—are much higher. Typically, these customers cannot afford large upfront costs, so payback can only be achieved over an extended period, or is simply not feasible. Thus, innovative delivery mechanisms are required for sustainable electricity supply to remote areas.

There are already a range of options for remote electrification that may have the potential for scale-up and sustainability. Following the International Energy Agency's (IEA) World Energy Outlook in 2011—which stated that the majority of new electricity connections in developing countries will be most cost-effective through decentralized systems—there has been an increasing focus on new delivery models for rural electrification (IEA 2011). The associated remote-energy-access initiatives for clean energy have not yet created fully receptive market conditions for private investment, but many new approaches are being implemented and may provide the foundation for future scale-up.

Until recently, support for non-grid electricity systems has been based upon funding allocations from public programs. But this approach is not sustainable. Based on the growing experience of rural electrification, there are good prospects for private sector business applications, though still not many successful installations. Grid-expansion efforts will certainly continue to draw on public finance and must be planned in a way that the grid will provide a service to customers who are located where the grid can be cost-effective. For off-grid applications, there is an urgent need for more pragmatic business models that can achieve the sustainable impact required.

Attracting private finance to any venture with high perceived risk will always be a challenge. But the good news is that there are a growing number of energy access activities with private sector involvement—such as the UN Foundation Energy Access Practitioners Network , SE4All's Clean Energy Mini-Grid (CEMG) High Impact Opportunity (HIO) , the U.S. Power Africa initiative , and the Alliance for Rural Electrification (ARE) . As a result, new delivery models are being developed and adapted to local conditions, although these adaptations inevitably increase the cost of replication and scale-up.

The bottom line is that there are still few examples of commercially viable installations, which offers an enormous market opportunity for private sector suppliers, with continued help from public funding sources. This chapter outlines the main risks and challenges perceived by investors and highlights examples of new delivery models that are being implemented—including consideration of the financing mechanisms introduced, and how policy and regulation and incentives are affecting their development. The chapter concludes that the best innovative energy service delivery models include several factors: (i) consideration of the demands, interests, and restrictions of local customers, including the desire to pay with mobile payments systems; (ii) strong partnerships along the entire supply chain, from the government and utilities to private sector service providers; and (iii) adaptation of market dynamics to local conditions to support successful, sustainable clean energy solutions.

HOW INVESTORS PERCEIVE RISKS AND CHALLENGES

The creation of appropriate market conditions for new delivery models requires a range of steps to help address the risks perceived by investors. The prospect of investment in often unfamiliar technology in unknown locations with uncertain regulatory requirements and an unfamiliar customer base creates a risk profile that simply does not compare favourably with other opportunities that may be available to investors. Thus, action is required to address the unfamiliarity of investors with energy access initiatives, which would help attract the necessary finance on terms that can allow affordable repayments by the target end-users.

For investors, confidence in the stability of market conditions is paramount to secure their required returns, usually requiring some evidence of a supportive policy framework. One of the key factors any investor takes into account is the payback period. For rural energy supplies, there are likely to be high upfront costs and customers with low levels of income, suggesting that affordable repayments must be extended over a longer timeframe than normal for similar financial needs. Reducing the perceived risk of payment default therefore requires some certainty over the future business environment. The lack of such clarity for rural electrification conditions in existing policy is often an unsurmountable barrier for any business seeking to attract finance for rural energy applications in developing countries.

For mini-grids, the unknown probability of future grid integration is a critical factor. Several mini-grids developers, including PowerGen, Husk Power Systems, and SunEdison Frontier Power, have identified this as a decisive business issue. The case of India is often highlighted, where the state electricity distribution companies (discoms) act with little regard to mini-grid developers and do not publicize in advance any plans for developing extensions to the central grid. Investors have proposed several solutions to safeguard investments in distributed, mini-grid solutions. These include: (i) allowing mini-grids to feed power into a central grid at a fair feed-in tariff; (ii) permitting discoms to enter into power purchase agreements with the mini-grid providers; and (iii) allowing the central grid utility to purchase the mini-grid upon interconnection subject to a set minimum return on investment, rather than negotiating a feed-in-tariff or purchase power agreement (PPA) (Jha 2015).

Another policy issue is duty exemption. Some governments have reduced or abolished customs duties for components being imported for mini-grid projects, in light of the social gains from rural electrification through mini-grids. But in practice, developers have found that negotiating the duty exemption carries significant risk and high transaction costs, discouraging them from even trying in some cases.

However, the key challenge centers on the need for accessible financing models—which are starting to be launched in the form of new finance and investment companies that focus on mini-grids and solar home systems (SHS). These firms, all established within the past few years, provide several means of financial support, including early-stage corporate investment, working capital, asset management, portfolio aggregation, and securitization. This increased capacity for financial management when dealing with remote customers has seen rapid growth in the SHS sector, with great potential also recognized for mini-grids. Business models should therefore always consider policy and financial factors, and recognize the link between the two. And the government should not only allay investor concerns about the level of risk but also deliver longer-term benefits (including lower technology import duties and VAT).

Decentralized electricity options can be successfully applied in many different locations worldwide, providing that the necessary policy framework is in place. As indicated in Chapter 1 of this report, it is also important to integrate energy access efforts within other sector-specific policies in order to leverage the inter-dependence. It is widely agreed by investors that the specifics are not as important as simply having a policy that is clear and actually put into practice.

One way to offset the investment risk is to allocate short-term public sector funding. This can enable project developers to offset upfront development costs and demonstrate innovative business frameworks for successful and sustainable future operation. Recognizing the need for such early-stage support, a range of international development organizations are active in facilitating the establishment of new delivery models that are based on grid-connected or off-grid renewable energy technologies. These programs can offer welcome support for potential project developers and help to attract longer term private investment.

This type of public sector subsidy is widely acknowledged as being helpful, but many developers have found that it is very difficult to access. That is why some mini-grid companies are proposing other frameworks that could be more streamlined and effective:

- Government subsidies to the institution financing the debt for mini-grid projects, which would reduce the developer's transaction costs. The subsidy could be used in different ways, from increasing the amount of credit available for a given project, to mitigating currency risk, to reducing interest rates and decreasing the cost of capital.
- Performance based operating subsidies, which would help mitigate customer revenue risk.
- Risk-adjusted capex and operating subsidies, potentially based on individual customer FICO score equivalents. A risk-adjusted connection subsidy or ongoing payment subsidy could function in a way similar to low-income housing subsidies.

To date there have been few examples of such facilities being made available, although public sector funders are increasingly aware of the need to address this constraint.

MARKETS, BUSINESS MODELS, AND TECHNOLOGY

The options for energy access expansion need to be targeted at appropriate markets. In general, the three areas of stand-alone systems, mini-grids, and grid extension are segregated and serviced by different groups of suppliers.

Markets Serviced by Stand-Alone Systems

Solar home systems and small-scale solar lights have been promoted for decades as solutions to energy poverty in developing countries. Since the 1980s, companies like Soluz in Latin America, microfinance institutions in Asia like SEEDS, and the Indian Renewable Energy Development Agency Ltd. (IREDA) have offered consumers credit to finance these systems. This model of coupling microfinance with renewable energy technology became known as "energy lending," was designed to increase access to modern energy services.

Yet despite the rapid and steady decline in the cost of these solar systems, consumers still face the financial hurdle of high upfront costs. As the CEO of Azuri, Simon Bransfield-Garth has stated, "a typical rural farmer who earns $2-3 per day would struggle to pay outright for a basic $70 solar home system." In addition, these consumers often incur a small ongoing cost related to candles for lighting and local vendors for batteries and cell phone charging.

What would it take to create a viable new market? The answer lies with a broad enabling environment. Energy lending has seen the adoption of millions of solar home systems (SHS) throughout the world—such as through IDCOL in Bangladesh, which financed at least 3 million systems as of 2014)—but examples of success have inevitably included a wide range of support measures (Walters 2015). Government or development program intervention is usually evident, as well as training for local microfinance institutions on underwriting, installation, and service, and a strong ground presence with teams of loan officers and technicians. Some form of direct subsidy is also often required. In the case of IDCOL, customers had access to government grants that reduced the SHS price, especially low-income ones, for whom the grant offset a significant proportion of the cost of smaller systems.

Getting these pieces to fall into place is a challenge that not every market has overcome, and as a result, there are still major challenges to the continued sustainability of these systems. Even in those countries (such as Bangladesh) that have achieved good SHS installation rates, a number of tasks must be undertaken to ensure any further market expansion, including: (i) developing a competitive low-cost SHS manufacturing industry locally to reduce dependence on imports; (ii) developing and ensuring quality standards for these systems; and (iii) creating more sustainable business models (Smart-Villages 2015).

One key factor for success in supplying capital-intensive equipment to a market with limited payback capacity is a good financial model. Approaches vary, but companies typically raise some capital from sources that do not demand fully commercial returns (such as public sector funders or philanthropic/impact investors) to act as a credit cushion against which they can gear up additional commercial capital. Some examples of companies raising funds to finance their plans for scale up in Africa include M-KOPA in Kenya, Mobisol in Tanzania and Rwanda, and Nova Lumos in Nigeria and Guinea (Table 5.1).

Another key success factor is the establishment of sustainable retail, distribution, and servicing channels. For companies involved with the supply of electricity generation systems for individual households in remote areas, these channels can be almost as costly to develop and maintain as the equipment itself. This explains why the prices of equipment in rural areas are usually well above the international wholesale norms. System suppliers have different strategies to address this market. Some companies (such as M-KOPA, Mobisol, Off Grid Electric) have built up their own distribution channels, while others have partnered with mobile phone companies to adapt existing distribution channels (such as Lumos in Nigeria linking with MTN). Either way, effective distribution channels cannot be built overnight, and they are a key constraint on how quickly companies can scale-up.

Solar PV systems are the most common power source for such individual stand-alone electricity supplies, but the rate of expansion depends upon customer access to finance. The off-grid solar market is projected to grow from about $540 million in 2014 to $2 billion by 2024—with Africa and South Asia the major markets. Access to disposable cash income, credit worthiness of the borrower, and availability of credit facilities are factors that determine the success of this model (Navigant Research 2014).

Pay-as-you-go (PAYG) models have become increasingly attractive in many markets. This is based upon experience suggesting that, even under local conditions in remote markets, the key to a cost-effective stand-alone

TABLE 5.1 Recent capital raising by off-grid electricity companies in Africa

COMPANY	GEOGRAPHICAL FOCUS	DATE	AMOUNT	KEY SOURCES
M-KOPA	East Africa, esp. Kenya	Dec-15	$15m	High Net Worth
		Feb-15	$12.45m	Institutional impact,
		Dec-13	$20m	philanthropic investors
Azuri Technologies	Sub-Saharan Africa	Jul-13	$13m	US AID DIV (Development Innovation Ventures) grant
		Feb-13		Barclays working capital loan
		Nov-12		Equity, debt & grants—lead VC investor IP Group Plc
Off Grid Electric	Tanzania, Rwanda	Oct-15	$25m	DBL Partners
		Dec-14	$16m	SolarCity
		Early-14	$7m	Other institutional and impact investors
Mobisol	Tanzania, Rwanda	Jul-15	€10.7m	DEG (loan) Other funding: European Development Fund, Africa Energy Challenge Fund
Nova Lumos	Nigeria, Guinea	Oct-15	$15m	OPIC (loan) Other funding: Israel Cleantech Ventures
Bbox	Kenya, Rwanda, Uganda	Mar-15	$3m	Private equity (inc. Bamboo Finance)
		Nov-13	$1.9m	Other funding: Khosla Impact, DOEN Foundation
Fenix International	East Africa	Jan-15	$12.6m	Corporate: GDF Suez, Schneider Electric, Orange Other funding: VC, Impact investors
Greenlight Planet	40 countries; mostly Asia and Africa Started in India	Feb-15	$10m	Fidelity Growth Partners
		Apr-12	$4m	Bamboo Finance

energy system business is a finance model that matches affordable pricing for the target consumers with an adequate return on investment for the supplier. PAYG solar companies seek to provide energy services at a price point that is less than, or equal to, consumers' current spending on kerosene, candles, batteries, and other low-quality energy services. Providers are incentivized to offer quality after sales service, since a user's ongoing payments are tied to the system continuing to function.

PAYG providers can take one of two approaches to financing the system to the consumer:

- An indefinite fee for service in which the consumer never owns the system itself, but rather merely pays for the ability to use it. Payments are typically made on the basis of when the consumer needs power and can afford it.
- The consumer eventually owns the system after paying off the principal of the system cost—and the consumer must make discrete payments, typically on a daily, weekly, or monthly basis (thereby resembling a typical financing arrangement).

With either approach, the system "locks" to prevent consumption if the user runs out of credit or if the financing payment has not been made. Under the ownership model, the system will automatically unlock permanently once the user has paid off the full amount of the loan. Also in both models, users usually make an upfront payment to cover installation costs and to reduce the financial risk exposure of the provider.

PAYG finance is quickly becoming a successor to energy lending for solar power in developing countries (Box 5.1). This is due to early experience of successful implementation, showing very high rates of growth. Lighting Global (a World Bank platform) has estimated that there are 32 PAYG companies in 30 countries, many of them in Africa (Global Lighting, 2014). They use existing mobile payment systems or scratch cards for fee collection. Consumers benefit from increased affordability, increased confidence in the product, and access to maintenance services. For the supplier, PAYG lowers the transaction costs without the need for a significant rural financial infrastructure, and it reduces the cost and risk of doing business. M-KOPA Solar is an often-cited example of a firm with good experience of successful PAYG applications, having connected more than 330,000 homes in Kenya, Tanzania, and Uganda to solar power with over 500 new homes being added every day (Economist 2016).

Markets Serviced by Mini-Grids

It is widely believed that mini-grids will play an essential role in meeting the goal of electricity access for all (SE4All 2015). Mini-grids can be a viable and cost effective route to electrification where the distance from the grid is too large and the population density too low to economically justify a grid connection. Mini-grids provide an enhanced service level compared with individual household systems and, depending upon local resources and technologies employed, can be comparable to a well-functioning grid. However, despite advances in technology, and associated cost reductions, the pace at which clean energy mini-grids are being developed and financed remains slow due to a range of barriers (see Chapter 3).

High upfront costs and long-term payback are particular challenges for mini-grids businesses. The status quo of supplier load control and monthly tariffs for mini-grid systems inhibits the quality of service and any potential for financial sustainability. However, recent technology innovations on metering and control processes by firms (such as Powerhive, SteamaCo, SparkMeter, and Inensus) are enabling equipment to be downsized, thereby cutting the costs of providing small village-scale grids. New innovations are enabling pre-payment, mobile payments, load limits, and remote monitoring and control to improve mini-grid operations.

The cost of data gathering required to establish future mini-grid markets has also been reduced through access to GIS (geographic information system) data on handheld devices that can be used by local staff. This has helped to lower the level of upfront investment required for project development, facilitating broader aggregation options. The pooling of contacts from individual households or small businesses in a rural community, while maintaining transparent supporting data, is a key ingredient for recently established businesses in developing countries. This has triggered the beginnings of scale-up by a number of energy companies and financing organizations that are dealing with such mini-grid applications.

However, for sustainable scale-up, the mini-grids delivery model must reflect consumer preferences and include an appropriate financing mechanism. As with grid extension, the mini-grids model is not constrained by any need for consumers to have financial capital available. Instead, the upfront investment is made by the supply company and is recovered through sales of electricity. Debt and equity financing is generally from private sources, often with some funding from credit or technical assistance facilities set up by donors. But an evaluation of seven micro-grids by the UN Foundation noted that crucial to the success of a micro-grid business was keeping customers satisfied through service and reliability (Schnitzer 2014). Full revenue collection also requires appropriate tariff design, tariff collection mechanisms, maintenance and contractor performance, theft management, marketing/promotion for demand growth, load limits, and local training and institutionalization. Addressing all of these factors is crucial to business success in remote areas, and the lack of such multi-faceted approaches helps to explain the slow rate of market development.

Companies large and small, new and old, are using a wide range of different business models in an attempt to release the full mini-grid market potential. Recognizing the cost-effectiveness of delivering power through mini-grids, numerous private sector players have sought to capture the massive opportunity inherent in providing access to electricity. Many different approaches have been formulated to address the diversity of consumer ability to pay, consumer location, policy and regulatory environments, and available financing found throughout the world. These experiences, even those that are unsuccessful, can offer lessons for future mini-grid market development.

The rationale articulated by mini-grid developers for focusing their efforts on these systems, rather than stand-alone applications, is driven by a "bet on the future." Developers are assuming that individuals in communities (which together can create significant local economies) will eventually be able to afford TVs, radios, refrigerators, and other appliances in their houses. They will also start to invest in so-called "productive uses"—the engines of small businesses. On this basis, the demand for electricity to power all the associated devices will clearly grow significantly in the future. This will quickly surpass the capacity that can be offered by stand-alone systems but is unlikely to reach the threshold required to justify full grid extension for some time (sufficient for an acceptable return on investment).

As many developers are discovering, access to 24/7 "on demand" electricity of unlimited quantities is not necessarily aligned with the realities at both the local and national level. Project developers have identified several specific barriers, including:

- Numerous cases of time-consuming or expensive customs processes that are frequently difficult to navigate.
- Local politics:
  - One developer cancelled a project in India because the two opposing clans in the village made clear that if the solar PV plant was in the other clan's territory, they would sabotage it.
  - Several projects falling into disrepair as a result of communities' expectations of the impending arrival of the central grid created by empty promises of local politicians.
- Unwillingness of financiers to provide levels of funding on the necessary terms to make projects viable.

Unlike the perspective held by large companies in the energy access space, small developers report that the biggest barrier to scale is financing. Emerging delivery models must take account of experience to date, which has concluded that:

- Achieving scale and cost-effectiveness is the key challenge that will determine how well new delivery models can help to bring universal access to energy by 2030.
- Demonstration of the commercial viability for remote energy access solutions is a key target.

BOX 5.1

Replicating East Africa's Pay-as-You-Go Success Story

East Africa—and in particular, Kenya—has a long history of building off-grid solar markets. In Kenya, the market for solar PV systems began back in the mid-1980s, and by the early 2000s, some 30,000 systems were being installed per year—most of them through an unsubsidized free market. Solar was then (and is now again) the most common source of electricity connections in rural Kenya. However, the solar home systems were relatively expensive, and without the involvement of micro-finance institutions, which were driving off-grid solar market expansion in Asia, the market remained very shallow. In addition, there were concerns about the quality of the systems in the market.

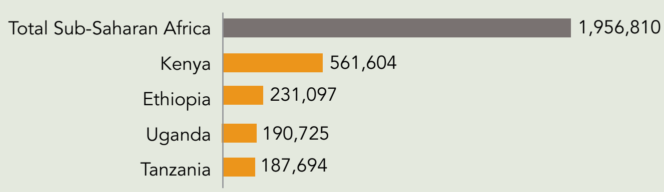
But in 2010, the market got a new impetus when a new generation of pico-PV products emerged—driven by technology advancements (such as new LED lighting, falling solar PV prices, and improved energy storage technologies like lithium-ion batteries). Supported by the World Bank Group Lighting Africa program, which introduced quality standards and provided early market support, off-grid solar product sales in Kenya and neighboring East African countries exploded—reaching almost 2 million in Sub-Saharan Africa in 2016, with Kenya accounting for almost half (Figure B5.1.1). This growth was supported by a favorable fiscal policy, as solar products benefitted from the East Africa Community's customs duty and VAT exemptions. Plus, the East African countries rank well on a favorable general business environment (as in the Doing Business survey), along with a favorable off-grid renewable business (for example, ClimateScope and RISE).

The parallel telecom/IT revolution has added another dimension to this growth. The rapid spread of mobile phones in rural areas became one of the key drivers of demand for solar PV products, which have quickly integrated cell phone charging capabilities. Kenya is also the birth place of mobile money. The mobile platform M-Pesa ("M" for mobile, "Pesa" for money) was launched by the Kenyan telecom company Safaricom in 2007 and quickly became a standard platform for financial transactions. Today, East Africa accounts for 34 percent of all registered mobile accounts globally. The high GSM coverage, variety of smart-metering technologies, and fast spread of mobile money gave rise to the pay-as-you-go (PAYG) business model—together overcoming the main affordability constraint for solar home systems (SHS) by allowing customers to pay in small increments. It is estimated that by end 2016, there were about 700,000 systems installed on the PAYG platform in Kenya alone.

Although the PAYG business model is still very new, and different companies are exploring variations of this business model, certain trends are emerging (based on interviews carried out for the SEAR case study in the first quarter of 2016)

FIGURE B5.1.1 Kenya leads the way in Africa's off-grid solar product sales

(Off-grid solar products sales in SSA, first half 2016



Source: GOGLA.

- There are already a wide range of implementation examples from which many lessons (good and bad) can be learned.
- All applications are different, making them more difficult to replicate directly.
- A key barrier is the business model—there are few successes without long-term public finance, though this can be limited to a single contribution at the outset of any new development.

The combination of barriers, and uncertainty over best practice, means that no clear approach has yet been defined to ensure the sustainable application of mini-grids. Pre-payment alone (such as the PAYG model used successfully with stand-alone systems) is insufficient to solve the problems faced by mini-grid operators. Mini-grids by definition are extremely capacity constrained—they are characterized by just one generation source. As a result, they are extremely susceptible to brownouts (periods of low voltage that cause lights to dim and other appliances to not function properly) or even blackouts. Both conditions are a result of a total system load that strains the output capacity of the generation source. To address this problem, and thereby maintain system reliability, mini-grid operators have tried numerous methods to limit consumer load. Typically, this includes:

- Customer contracts or agreements wherein the customer agrees to limit their load by, for example, not installing more than the agreed upon number of outlets or light fixtures, or not using high-consumption appliances such as incandescent light bulbs or resistive heating devices (like irons and cookers).
- Installation of Miniature Circuit Breakers (MCBs) or Electronic Load Controllers/Electronic Control Units (ELCs/ECUs) on customer connections. These devices set a fixed limit on consumer consumption that cannot be exceeded as long as they are wired into the circuit.

Neither solution has been found to be effective over time. Customer agreements are easily violated in the absence of a strong enforcement mechanism. MCBs and ELCs are easily bypassed. The result can be seen as a "tragedy of the commons," evidenced by mini-grids as disparate as those in Haiti, India, Malaysia, and throughout Sub-Saharan Africa.

There are clearly a wide range of barriers to the successful application of mini-grids in remote areas but, despite

- *Off-grid energy companies are moving from cash-sales to PAYG.* The interviewed businesses currently report on average a 50-50 split between cash sales and PAYG. However, they forecast a significantly higher growth of PAYG (median growth of 300%), which will irrefutably shift the balance in favor of PAYG.
- *Consumer demand for larger systems is rising.* In the early years, most PAYG companies focused on launching basic service products, offering lighting and cell phone charging (typically corresponding to SE4ALL Tier 1). Today, 85% of the companies interviewed either currently integrate a TV in the system or plan to introduce it in near future (products typically corresponding to SE4ALL Tier 2).
- *Rent to Own is becoming the predominant PAYG service model.* The market research and companies' experience have revealed that East African customers prefer owning the system rather than renting or leasing them perpetually, regardless of the automatic upgrades typically offered under the perpetual lease. Of the interviewed companies, over 90% operate under a rent-to-own service model.
- *GSM integration and mobile money are becoming standard features.* Payments with mobile money, such as M-pesa in Kenya, tend to be more reliable, easier for the customer to make, and faster for the company to receive. As a result, the majority of PAYG companies are relying on mobile money transactions.
- *New entrants are less vertically integrated than the early entrants.* The first PAYG pioneers have typically been vertically integrated companies controlling all aspects of the value chain—from design and manufacturing of PAYG hardware and software platforms to system integration, distribution, marketing, consumer awareness, and sales. The vertical integration of early PAYG companies was to some extent a necessity as the market was new and companies offering specialized business-to-business services did not exist. But now there is a growing number of specialized companies offering value chain services for PAYG. This reduces entry costs for new PAYG companies, which can focus on their business model and relationship with customers, instead of building technology and systems.

Overall, the interviewed companies and investors appear to be optimistic about the transferability of the model to other geographies. This optimism seems to be justified by the recent emergence of PAYG companies in other countries in Sub-Saharan Africa (such as Nigeria, Ghana, Cote d'Ivoire, and Mozambique). However, the pace of progress is likely to be influenced by the presence or absence of the factors behind the East African success. For now, it appears that the countries most likely to benefit are those with a large unelectrified population, mobile money platforms, consumer knowledge of solar products, and a friendly off-grid business environment (including the fiscal regime).

SEAR Case Study, Forthcoming.

these challenges, progress is being made. Ongoing concerns include the need for continued government support for mini-grids in areas where there is no grid expansion planned for the foreseeable future, financial barriers, and affordable tariffs for rural consumers. However, the sector is still growing rather than retreating. Unlike the historic course of private sector participation in the power sector in developing countries—where progress was usually defined by centralized agreement with the national utility— mini-grid companies recognize that success entails reaching a very large number of individual customers, and they are working to implement business models that can provide acceptable returns under these conditions.

A wide range of providers have attempted to introduce business models for the sustainable supply, maintenance, and operation of clean energy mini-grids in developing countries. There is still no single approach that is recognized as the best option –although effectively responding to local conditions is a key requirement for success and demands tailored solutions. There are, however, common features that can be identified by examining different examples of current business applications from 10 of the leading operators (Table 5.2).

Markets Serviced by Grid Extension

Only 30 percent of the population in Sub-Saharan Africa, and 60 percent in South-East Asia, are connected to an electricity grid (IFC 2012). Even when such grid electricity is available, the service experienced by many consumers is very unreliable with inconsistent supply and frequent power outages. As a result, many users, particularly businesses, must also invest in a back-up generation facility, which is often diesel-powered, inefficient and therefore costly, as well as damaging to the environment. What is needed are innovative delivery models to enable grid extension to become a cost-effective option in the future.

The large number of potential grid users (usually in urban or per-urban areas) who currently rely on alternative electricity generation facilities represent a key target market for local utilities. However, there are two key barriers that make it tougher to expand to low-income communities: effective routes for payment and operational efficiency. These issues are compounded for utilities that would like to extend their services to more rural areas, but prospective solutions are constrained by policy restrictions—such as fixed tariff structures that are unrepresentative of the increased costs of supply.

TABLE 5.2 A big array of emerging delivery models for mini grids

COMPANY	CURRENT OUTREACH	TARGET	COUNTRIES	ENERGY SOURCE	SIZE RANGE	FOCUS/INNOVATION
E.ON	7 systems, 420 customers	1m people in 10 years	Tanzania diesel	Solar, bio-	6–12kW	Standardisation for scale; Establish track record for finance Cellphone payment
GHAM POWER	3 micro-grids	>100 micro-grids in 10 years	Nepal	Solar	1–10kW	PPA with N-cell (telecoms) for reduced risk revenue stream Rent-to-own agreements
HUSK POWER	15,000 house-holds, several 100 businesses	75,000 households, 10,000 businesses, 125 agro units	India Tanzania	Biomass, Solar	15–250kW (biomass); 20kW (solar)	Accept >5 year payback Targeting 8-10 year loans Rural empowerment 3-year expansion plan Inclusive business model
INENSUS	Supports mini-grid development in Africa with related management systems and consultancy		Senegal	Solar, wind	5–10kW	Low-cost smartcard meter Sale of "electricity blocks" "MicroPowerEconomy" delivery system—flexible tariffs & micro-credit
M-KOPA	340,000 homes (Mar 16)	+500 homes/day	Kenya, Tanzania, Uganda,	Solar	5–20W	PAYG business model Small SHS, LEDs & mobile phone charging services
POWERGEN (RENEWABLE ENERGY)	20+ mini-grids	50 mini-grids in 2016	Kenya & Tanzania, Zambia	Solar	1–6kW	Mini-grids compatible with central grid standards
POWERHIVE	4 sites, 1500 people (~300 connections)	100 villages	Kenya, Philippines (Africa/Asia expansion)	Solar	~20kW	Integrated tech system; Mobile money networks for pre-payment Dedicated software – predict revenue streams;
RUAHA POWER	1 pilot project (JV with Husk Power)	100 projects	Tanzania	Solar, biomass	300kW	Business model without subsidies Build Own Operate model Pre-payment meters
SPARKMETER	3 Earthspark mini-grids in Haiti	No fixed target	Asia, Africa, Latin America	Service for all types of mini -grids	0–500W	Metering with mobile payment system Cloud-based software "Gateway" usage dbase
SUNEDISON*	Pilots (with partners—not owned)	20m customers in 5 years	India, Tanzania	Solar	1–5kW	Set own tariffs; Aim for standard banking terms to finance projects

* SunEdison, once the fastest-growing U.S. renewable energy company, filed for bankruptcy protection on April 21, 2016.

The good news is that the value of flexible payment options are increasingly being recognized and have been successfully introduced in some larger developing economies (like Brazil and India). Typical routes to successful financial models have included the installation of prepayment meters, providing payment flexibility, and offering financial incentives to consumers using legal connections. But payment facilities can only be effective if the supply of electricity is sufficiently reliable. Thus, local utilities need to become more efficient, which will mean developing more appropriate business models, infrastructure, and local capacity building.

The financial model governing the supply of clean energy to any existing grid is often the determining factor for success. This inevitably requires a balance between customer affordability and sufficient margins for the investor. One option is for a private company to finance and supply renewable electricity to the grid-owner (usually the national utility) under a power purchase contract at a competitively awarded or negotiated price, or feed-in-tariff agreed in advance. Another business model for grid extension can be effective when the grid reaches a community containing households that already have individual systems supplying electricity from renewable energy, most often from solar power. The building owners can then sell electricity back to the utility on a net metered basis.

In the on-grid power sector, successfully developing new infrastructure relies on effective partnerships between all of the key stakeholders, which requires lengthy negotiation. The incumbent utilities, the different layers of government, the host communities and households, and private sector firms must all identify common interests and complimentary inputs that bring added value from their perspectives. For grid extension to remote communities, the needs and priorities of all of these players can often only be aligned following extended interaction over a long timeframe. And once the agreement to initiate is reached, there are inevitably differences and tensions that emerge with respect to ongoing operations, maintenance, and pricing levels. Cost-effective grid extension to remote locations can therefore become an insurmountable challenge, with different stakeholders only satisfied with different solutions geared more toward their individual needs.

As a result, the best way for developing countries to achieve financially sustainable grid extension is to encourage private sector suppliers to participate. In many countries, the national grid operator struggles to maintain the existing structure to a standard that can provide a satisfactory service at acceptable cost—primarily due to limited financial resources. Given that the existing arrangement often involves a significant government subsidy, the prospect of grid extension represents a future drain on public funds. Involving the private sector can introduce greater efficiencies and new business models that enable the grid to be connected to areas that may otherwise seem unviable. However, new approaches require sufficient flexibility in the governing policy frameworks. This will mean revised tariff structures, appropriate policies to allow grid connection to informal settlements, and incentives to offset upfront investment costs.

Take the case of Tata Power Delhi Distribution Limited (TPDDL), which illustrates how the private sector's drive for efficiency and its ability to innovate can turn loss-making customers in poor neighborhoods into profit centers—while delivering important economic benefits for the poor (Box 5.2). This was done through a smart adaptation of a business model, which put customer needs in first place, and an emphasis on engaging and building trust with the communities. The government, including the regulator, supported this innovation and allowed modifications of the existing regulatory regime to account for the special characteristics of slum areas.

Business model innovation is critical if grid extension is to provide a means for increasing the rate of electricity access in developing countries. The mismatch between grid expansion costs and affordability to low-income customers needs to be addressed. However, the way in which this takes place will be particular to each country's specific circumstances, development needs, and cultural norms. These conditions, particularly in countries with dispersed populations, present a major challenge to national electricity providers in developing countries. Even with the best intentions, new models are often insufficient to justify further investment in grid extension. This suggests that, particularly in Africa, alternatives to further grid coverage need to be developed—as Kenya showed in its Last Mile Connectivity Program (Box 5.3).

OPPORTUNITIES FOR BUSINESS IN THE OFF-GRID MARKET?

What are the opportunities for business in the off-grid market? There are a range of factors that can be identified using the experience of rural energy applications to date that together form a critical foundation for any successful intervention. A common underlying theme is that the successful development of new business relies on establishing good partnerships between all relevant stakeholders. But the way in which this takes place will be particular to countries' specific circumstances, development needs, and cultural norms. What is key is that the programs and strategies include institutional, technical, economic, and financial design and implementation arrangements that ensure their efficient execution and their financial and operational sustainability.

Increasingly, operators in the off-grid market are dealing strategically with a set of factors that are opening space for business—notably, (i) thinking broader than energy; (ii) seeking a mix of public and private finance; (iii) combining investment with assistance; (iv) dealing with affordability issues in context; (v) engaging with consumers; and (vi) providing after-sales service.

Thinking Broader than Energy

For PAYG providers, future opportunities lie well beyond energy. If they can effectively address the immediate challenges and scale up their energy business, they will be able to develop mechanisms to manage an ongoing financing relationship with lower-income customers that are the hardest to serve. Once established, there is virtually no limit to the products and services that might be offered through this distribution channel, with existing customers being less costly to serve, and therefore more profitable. Upon completion of a financed energy purchase, customers do more than acquire a solar unit, they also build a positive credit history and access an ideal form of collateral, which they can then refinance.

There is potential for some providers to make the transition from energy company to asset finance company. M-KOPA, for example, now offers a self-described "double dividend": (i) the money saved on kerosene when customers start paying for their initial solar unit; and (ii) the ability to "re-finance the unit, once it has been paid off, and take cash out (to a mobile wallet) or purchase another product or service on credit"(M-KOPA 2015). M-KOPA offers financing on items such as fuel-efficient cook stoves, water tanks, bicycles, and smartphones, and it has set up a trial program in which customers can direct the cash from refinancing toward school fees. The combination of a productive and desirable commodity (energy), digital payments linked to PAYG technology, and robust service/distribution networks makes off-grid solar an ideal entry point for scalable consumer financing. But caution must be taken: consumer financing is a powerful tool, and it is a potentially dangerous one. Responsible lenders and diligent regulators must work together to ensure that finance is used to improve development outcomes, not merely to push product sales.

There is space for further energy-finance innovation. Partnerships with local financial institutions could bring additional financial services to customers that were until recently unbanked, while lowering the cost of capital and foreign exchange risk for energy companies. Alternatively, energy companies could follow the lead of durable goods retailers in Latin America, some of which have transitioned into full-service retail banks (Winiecki 2015). If PAYG solar companies can accurately assess the risk of lending to unbanked customers while expanding PAYG solar offer-

BOX 5.2

Slum Electrification in New Delhi: A Private Utility Approach

Tata Power Delhi Distribution Limited (TPDDL) is a joint venture between Tata Power and the Delhi government, with the majority stake being held by Tata Power (51 percent). Since 2002, it has distributed electricity in the north and northwest parts of Delhi, serving a populace of 6 million—including about 1 million households across 860 slums in urban Delhi.

When TPDDL took over the distribution assets of the former state-owned utility in 2002, only about 5 percent of slum households had legal connections, and the overall technical and commercial losses were over 90 percent. The infrastructure was in a dilapidated state, there were no meters, and stealing was commonplace. Legalizing connections in slum areas was a part of TPDDL's overall drive to reduce losses. After reducing overall aggregate technical and commercial (AT&C) losses from 53 percent in 2002 to 15 percent in 2009, TPDDL began to target losses in slum areas. Recognizing that the regularization of slum connections would require a special "out of the box" approach, it created a new Special Consumer Group (SCG). The group got financial and human resources from the company to come up with a plan to legally connect slum consumers, reduce AT&C losses, and generate revenue.

The SCG began its engagement with slum communities by first trying to understand their needs and how electricity can help them meet those needs. From this engagement, TPDDL was gradually able to devise a new approach, anchored in the following principles:

- **Electricity is not a starting point for engaging slum dwellers.** TPDDL carried out a survey to better understand slum dwellers' needs. Understanding that electricity was not the highest need, it started engaging first through its Corporate Social Responsibility (CSR) program to accommodate the most pressing needs of slum dwellers. These CSR activities provided TPDDL with a strong foothold in the community and helped them create a trustworthy name for their company, setting the stage for slum electrification.
- **Slum consumers must be treated with respect.** The TPDDL treated slum customers on par with their other urban household customers and provided them with the same quality of supply and customer service. The company's electricity bill has become a form of an identity card, allowing TPDDL slum customers to avail themselves of other services provided by TPDDL or the government.
- **Getting an electricity connection should be easy.** One of the biggest hurdles to legalizing connections was the requirement of a land title to prove tenancy. To overcome this challenge, TPDDL proposed affidavits signed by slum customers waiving TPDDL's responsibility in case of any slum demolition or legal action by the government. Such an affidavit would be used in place of land titles to get an electricity connection. In addition, by holding camps for new connections in slum areas and helping people with the paper work, TPDDL proactively reached out to these communities rather than wait for them to come to their offices. This not only reduced meter installation time but also encouraged more households to seek legalized connections.
- **New connections should be affordable.** TPDDL understood that the upfront payment of $60 for obtaining a new connection was a challenge. Thus, they advocated with the regulator to reduce the cost of a new connection to $25, with upfront payment of only about $5.83, the rest being paid in monthly instalments. Billing dates were matched with salary/wage dates and varied for different slum clusters as agreed upon in consultation with the communities. Some customers were also allowed to pay their electricity bills in easier installments based on individual household circumstances and agreed upon by the TPDDL staff. "Any Time Payment Machines" were installed at various locations for easy bill payments, saving travel costs for slum customers.
- **Additional benefits linked to legal connections.** Having an individual meter with a proper paper bill not only provided a sense of pride for slum customers but also gave them a document — their electricity bill — to avail various services provided by TPDDL's CSR initiatives and other government agencies, including TPDDL's programs on medical health, vocational training, educational help for children and access to safe drinking water. TPDDL also provided legal customers with accidental insurance coverage. The premium for this insurance policy was being paid by TPDDL, and was a big driver for households to apply for new connections.
- **Community members are business partners.** TPDDL appointed women who were part of their CSR literacy centers as "Brand Ambassadors" to raise awareness about the benefits of legal connections and help facilitate new connections and bill payments. They also teamed up with the local community leaders to be their "Franchisees" by creating incentives for them to increase collection efficiency. Influential community leaders were appointed as Pradhans, to help TPDDL resolve disputes and pave the way for franchisees and brand ambassadors to operate in the area.

The efforts to win the hearts of slum dwellers paid off. The number of legal customers located in slum clusters doubled from 93,000 in 2009 to 175,000 in 2015. Revenues from the slum areas increased from $3 million in 2009-10 to $18 million in 2014-15. The technical and commercial losses were reduced from 68 percent to about 23 percent, and collection efficiency increased from 67 percent to 98 percent. In addition, CSR efforts have led to improvements in the living condition of 140,000 families and have provided livelihood opportunities to young men and women.

Thus, TPDDL has proven that slum electrification can be a profitable venture. It has not treated this as "charitable work" but as a successful business model to bring down technical and commercial losses and increase revenue generation in the slums—treating slum dwellers as valued customers. It has been a win-win situation, benefitting both the slum population and the company.

Sear Case Study forthcoming.

BOX 5.3

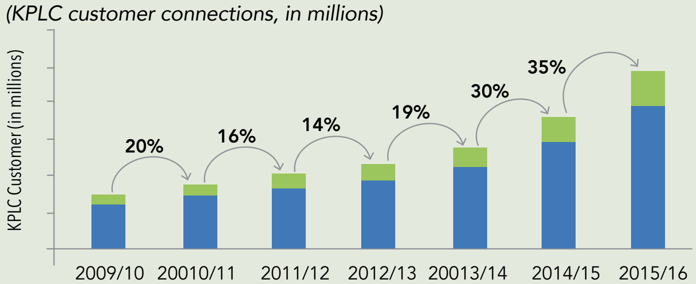
Kenya's Powerful Last Mile Connectivity Program

Kenya is embracing electrification as a flagship endeavor, with a focus on the distribution sector reaching all Kenyans with energy services by 2020. It has already emerged as a star in achieving progress on electrification—growing from 23 percent in 2009 to about 50 percent in 2016 (Figure B5.3.1)—underpinned by huge investments across the sector value chain. Today, there are about 5 million Kenya Power and Lighting Company (KPLC) consumers, with more than 1 million consumers added annually in the past two years.

The government's primary grid densification vehicle—the Last Mile Connectivity Program (LMCP)—seeks to connect all consumers within 600 meters of a transformer. It is supported by close to $700 million in donor resources (including the World Bank-financed Kenya Electricity Modernization Project) to speed up access in grid connected areas. Since Kenya's grid is almost exclusively concentrated in the central corridor, where there is the highest population density, this approach is considered the least cost way of harnessing economies of scale in network design with a potential of reaching about 70-80 percent of consumers.

Kenya is also leading the way on how to balance a rapidly growing electrification program with consumer affordability in a financially sustainable manner. The LMCP design encompasses a substantial decrease in the connection fee charged to household customers—from KES 35,000 ($343) to KES 15,000 ($147) (to be paid in instalments). However, such consumer connection charges are insufficient to cover the connection costs (of $1,000/connection) borne by KPLC. These new households are overwhelmingly low volume consumers paying a lifeline tariff and are cross-subsidized by other consumers in KPLC's overall revenue requirement to ERC. Initially, KPLC shouldered the gap with commercial loans, but this imposed an increasing burden on the utility's finances. There is now a two pronged approach: (i) in 2015, a World Bank Guarantee supported KPLC to restructure $500 million of short-term expensive commercial debt into a long-term maturity loan; and (ii) concessional debt by the donors to the government is being on-granted to KPLC for electrification purposes, thereby keeping the debt off KPLC's books.

FIGURE B5.3.1. Reaching out to all Kenyans
(KPLC customer connections, in millions)



Source: KPLC

ings to whole countries or regions, they will have built the "first scalable model for providing asset financing to unbanked consumers" (Winiecki 2015). PAYG companies have leveraged multiple innovations to reach their customers. How they evolve from here will determine their ultimate success (CGAP 2016)

Seeking a Mix of Public and Private Finance

Due to the capital-intensive nature of investments in energy access, debt financing is critical. Mini-grid project developers require project finance to cover the high initial cost of building out their grid infrastructure—like generation and distribution systems—and PAYG solar providers require debt in the form of working capital to finance their inventory. New financial firms are bringing innovations to the market for energy access to facilitate the flow of debt to mini-grid projects and PAYG solar companies alike (Box 5.4).

These financing mechanisms will dramatically revise the risk perspective of investors considering support for rural energy applications, along with offering excellent opportunities for preparing innovative business models. It is well-known that the financial mechanism used to address a potential market for energy supplies in remote areas will be a critical factor. Thus, much work on this issue is being undertaken by a wide range of stakeholders (including service providers, financiers, and academics). As always, when faced with new approaches for any business, the greatest risk and potential reward will be linked to the front-runners. But there needs to be greater efforts to raise awareness of such financing facilities to ensure that such leading project developers can access the latest tools available. In this way, the developers of new delivery models can consider the latest financial options and use or adapt those that best match local conditions.

Combining Investment with Assistance

While financial support is a necessary ingredient for success, well-informed investors recognize the value of offering something additional to address the risks presented by new technology, markets, and business models. Thus, innovative financiers are increasingly making a commitment to focus on the energy access sector, in effect, acknowledging the need for accompanying services. The unique challenges and undeveloped nature of providing access to energy for low-income households and busi-

BOX 5.4

How Financial Firms Can Support Innovation in the Off-Grid Marketplace

Persistent Energy Capital. A U.S.-Swiss boutique investment bank focused on off-grid renewable energy business estimates that there will be $2-3 billion of receivables held by energy access businesses by 2020 . Persistent Energy Capital is taking a unique approach to meet the working capital needs to fulfill these receivables. In December 2015, it launched a securitization of customer receivables called "Distributed Energy Asset Receivables", or "DEARs". This approach will be piloted using the receivables of PAYG solar providers in Kenya, issued by a special purpose vehicle, with additional projects soon after. The aim is "to develop a low risk debt instrument that will become standardized and rated by rating agencies so that investors can confidently invest across the energy access sector." Such an approach touches upon other crucial factors for the investment of debt into the sector that have been barriers to date, including the lack of lending by local financial institutions, and the lack of credit rating and quantitative risk assessment of end-user customers.

Lendable. A U.S. company that aims to build technology and financial products to attract impact investors is addressing the financial barriers for energy access companies through its Lendable Risk Engine. This tool applies statistical analysis to data, which is provided by the originators of receivables, to calculate portfolio risk for investors. Another barrier to lending in the sector is the transaction cost associated with deals. Lendable, along with others, is looking to solve this problem through deal standardization and platforms for investment. Their Lendable Marketplace "offers aggregated receivables across multiple originators, off the shelf and standard documentation, and transaction capabilities through existing SPEs and local service providers." The company expects to transact its first three deals in 2016.

CrossBoundary Energy. "Africa's first dedicated fund for commercial and industrial solar" is also working the standardization solution, but in the specific context of solar installers and project developers for commercial and industrial installations in Africa. CrossBoundary's target system size is between 50 kW and 5MW, and it is bringing PPAs to this under-financed and growing sector under its SolarAfrica platform. PPAs are already well-understood and widely used financial agreements for renewable and non-renewable projects, from small-scale residential installations to the largest generation projects. By developing standard terms and structure, it hopes to offer a "PPA in a box" solution to further reduce transaction costs to increase installers' and investors' capacity to realize projects. In Nairobi, it enabled the Garden City Mall to contract with a solar developer for 858 kW of PV for a carport, paid over 12 years, with no upfront cost.

SunFarmer. Like CrossBoundary, SunFarmer is focused on the institutional, commercial, and industrial market for solar power, using long-term debt and PPAs – rather than the PAYG solar or mini-grid market. In addition to reducing transaction costs through deal standardization, the U.S. company (whose first project was in Nepal) hopes to encourage local banks to begin lending to these projects by mitigating risk, both financially and technically. Financially, it structures credit enhancements like collateral support and first loss capital for the lender. Technically, it provides its due diligence services "to ensure good design, commissioning, and the existence of after-sales monitoring and support." It has also developed a real-time remote monitoring platform called EnergyX to monitor system performance over time.

nesses in developing countries underscores the need for this specialization. There are many government grant facilities, private grant competitions, foundations, family offices, and incubators that offer broad financial support for early-stage ventures, but few have the domain knowledge to accompany their investment with more than just dollars. Early stage energy access companies are either pioneering new technology, new markets, new business models, or a combination of these, which means that they require support across a wide range of activity.

Factor(E) Ventures uses customized engagements with its portfolio companies that address the unique technical or commercial aspects of the company that needs to be de-risked. This contrasts with other investment models that are based on hosting a "cohort" of early stage companies and providing them with somewhat generic support (like workshops and templates). While helpful, the latter approach is limited compared to the thousands of hours that Factor(E) (a U.S.-based company) offers in advisory support to their portfolio companies post-investment. This involvement has facilitated access to key partners in target markets, and it has helped provide follow-on investment to those portfolio companies that are ready for growth following Factor(E)'s seed-stage engagement.

Schneider Energy Access Ventures (EAV) recognizes this need in their portfolio companies and takes a similar approach. In addition to its investment, which its distribute in the range of $250,000 to $4 million across multiple rounds, the French company believes that providing technical assistance is critical to the success of their ventures.

Under an agreement with Schneider Electric, EAV can request up to 1,000 man-days of pro-bono work from Schneider employees per year for its portfolio companies. It can also access facilities and systems—such as overseas manufacturing plants or accounting systems—to accelerate the organizational development and maturity of their portfolio companies.

In short, a mix of public and private sector finance is required to establish, maintain, and grow the market in remote areas for clean energy applications. Energy access can be seen as a public sector obligation and therefore a government or donor contribution is justified to offset upfront costs. But private sector finance must be available to cover the full costs of operation, maintenance, and reinvestment in capital.

Dealing with Affordability Issues in Context

PAYG companies underscore not only the benefits of using their products—improvements to health, safety, and quality of light—but also the significant savings in expenditures that customers can recoup. M-KOPA estimates that a typical customer will save $750 in the first four years of using one of its systems. Relative to the approximate $1,100 it estimates consumers to have spent on kerosene and batteries in that time, this represents a saving of nearly 70 percent (Faris 2015)

To ensure affordability, there is a clear need to allow customer payback over an extended period. The duration and monthly cost of payback must be set at a level that can be justified to the customer, as well as being sufficient for the provider to recoup the cost of its assets. Marketing this balance in a way that attracts the interest of target customers is a feature of most PAYG companies. For example, Azuri's PayGo rent-to-own model is promoted as allowing consumers to spread the cost of ownership of a solar home system across a period of 18 months.

There is also an inevitable trade-off between the level of upfront costs and the duration of customer payments. Off-grid Electric (OGE) prides itself on offering what it describes as the lowest down payment and lowest ongoing payment price point in the industry. However, the customer pays for the system as a service over a 10-year period. OGE sees this as comparable to a utility model, and includes ongoing quality assurance over the entire contract period. This contrasts with the rent-to-own model, where the customer achieves full payment for the system over a much shorter period, but will then have to cover maintenance expenses and equipment replacement costs.

Introducing appropriate tariff policies (at the national or local level) is another way to address this challenging issue of balancing affordability and sufficient revenue to maintain the operational sustainability of the system. Past analysis by the World Bank (in 2008) indicated that poor consumers are willing to pay for electricity and often at levels that are higher than the long-term cost of supply, making a financially sustainable model possible. A well-designed tariff policy will ensure the poorest consumers can afford to meet their basic needs, while collecting sufficient overall revenue to allow operational sustainability (WBCSD 2012).

Engaging with consumers

There is a basic condition for any successful business anywhere in the world—know your customer! It is often stated that all locations for non-grid energy applications are different, with local resources, practices, priority needs, and traditional customs all varying between different communities. The solution is often quoted as a "bottom-up" approach in the context of rural development. In fact, this requirement is no different in rural Africa and is well-recognized by those companies that are making advances in this area.

Provision for such consumer engagement must be included in any business model aiming to address energy access in developing countries. Similar to the establishment of sales teams and special financing arrangements found in OECD countries for the adoption of residential rooftop solar PV by providers like SolarCity and SunRun, PAYG companies working in Africa are building out vast field-based sales teams in addition to their sophisticated IT-based financing capabilities. These distributors, including market leaders Off-Grid Electric and M-KOPA, employ a variety of strategies to drive sales—such as door to door sales, local events, and community meetings. The value of close interaction with the target market is well understood.

However, ensuring consumer engagement in remote rural areas is complicated by the high level of awareness-raising required to inform potential customers of the options available. As a result, providers too often impose externally designed interventions rather than responding to customer preferences. The "bottom-up" approach is standard business practice worldwide and must be implemented in order for any company to provide customers with sustainable energy access.

Providing After-Sales Service

Emerging delivery models for remote energy supplies are now placing a much greater value on customer service and retention. This is enhanced by the long-term payback period that is often required and must be effectively managed by the supplier. Historically, recognition of the end-user's needs, interests, and values has not been a priority for energy access initiatives in developing countries. These have generally been driven by donor funding, so the customer for the service provider has been the funder rather than the householders who are expected to use the systems installed. But addressing these energy needs through private business is leading to greater recognition of the end-user as the customer.

Insufficient after-sales service results in system failure, market spoilage, and the unsustainable operation of small-scale rural energy businesses. The PAYG business model improves outcomes for consumers not only because it increases adoption through financial access, but also because it can provide better after-sales service. Unlike cash sales and energy lending models, PAYG providers are strongly incentivized to ensure a reliable system operation on an ongoing basis. Under a standard payback business model, consumers will not continue to make payments to use the system if the system is not functioning.

Leading companies in the PAYG solar space are particularly proactive about after-sales service. For example, M-KOPA has integrated a SIM card into its systems—

enabling it to not only process customer payments via mobile money and automatically "unlock" systems when appropriate but also remotely monitor the health of its customers' systems. As a recent Bloomberg Businessweek article noted: "Workers at its call center can already pull up graphs showing how a customer's battery is charging and discharging, allowing them to spot duds to either fix or to swap. They can also look at the performance of the solar panels over time, detecting when a panel has been mounted on the wrong side of a roof or if it's gathered dust and needs to be wiped clean"(Faris 2015). This proactive approach to customer service is revolutionary in the context of energy access.

Another option for remote monitoring capabilities is to intelligently manage a user's system based on usage patterns and weather analysis. This is the approach adopted by Azuri. As Azuri CEO Simon Bransfield-Garth has described: "In the rainy season, solar home systems have to be effectively over-sized to deal with the poor weather, meaning they either need to be more expensive all year round, or that they perform less well at times, to the point that consumers may have to revert to traditional energy sources." In response to this problem, Azuri is using an internally developed enabling technology called HomeSmart™ to improve system performance by dynamically adjusting the brightness of the system's lights according to the available power. This eliminates the cost of over-sizing the system, while enhancing the customer experience.

Despite the evident benefits, longer-term customer interaction is often not a familiar process in rural areas of developing countries, so training to build local skills and awareness must be factored in to any delivery model. Local management and operation of an energy access business is necessary to achieve cost-effective long-term service delivery. International coordination can be justified to initiate any such intervention, but is usually not viable after this start-up period. Thus, building local capacity to support longer-term business operation and development must be a priority.

CONCLUSION

Despite increasing efforts to develop commercially viable operations for the sustainable expansion of clean energy technology applications in remote areas, there are still very few delivery models that have been successful at scale. This presents an enormous market opportunity for private sector suppliers, though the continued involvement of public funding sources will be required to build business models that are feasible under local conditions with an acceptable level of risk to investors. The public/private economic model that will be required must take full account of broader needs, such as links to policy, integrated technology applications, and the building of local capacity to ensure cost-effective local support structures. Partnerships with local stakeholders—including government, utilities, the host communities and households, and private sector firms along the supply chain—are necessary for the successful development of any new energy access business.

Based on the innovative energy service delivery models that are currently emerging, there are several common factors that must be taken into account to achieve positive, sustainable results. First, there is a need for different approaches in different locations, although the broad principles for success can be identified, thereby offering a framework for effective market development. Second, greater consideration must be given not only to the financial model but also the demands, interests, and restrictions of local customers—with mobile payment systems required to provide customer convenience. Third, strong partnerships must be developed along the entire supply chain, from the government and utilities that set the context, to the private sector service providers, to the communities and households that represent the demand. Market dynamics are as apparent in developing countries as elsewhere, but they must be carefully adapted to local conditions to support successful, sustainable, clean energy solutions.

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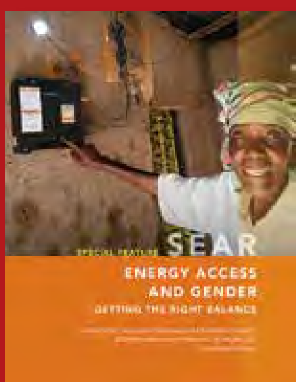

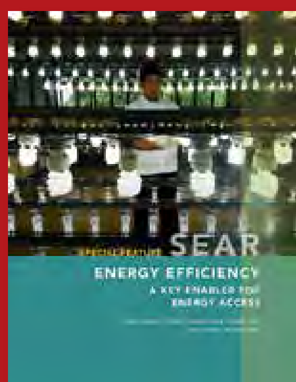

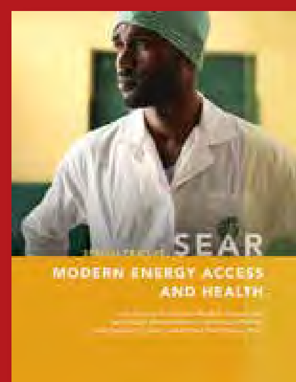

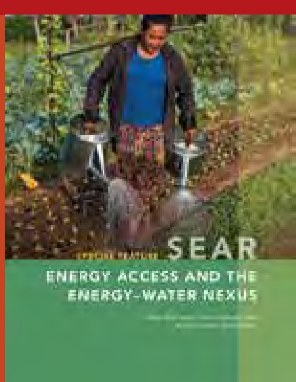

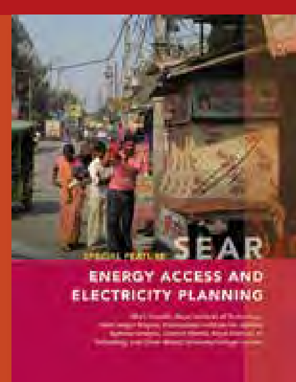

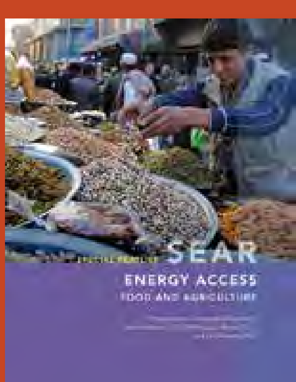

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