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STRATEGIES FOR EXPANDING UNIVERSAL ACCESS TO ELECTRICITY SERVICES FOR DEVELOPMENT

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EXECUTIVE SUMMARY

This paper proposes a new approach to scaling electricity access that aims not only to provide electricity services to unserved or underserved populations but to ensure that those services are appropriately matched to people's development needs.

The work of the World Bank's Energy Sector Management Assistance Program (ESMAP) has already demonstrated that people's access to electricity supply cannot be understood as a binary issue of "connected/not connected." ESMAP's Multi-tier Framework for electricity access defines five tiers of access, each tier involving progressively higher demands in terms of power delivery and hours of availability. It emphasizes the real potential of nontraditional energy supply systems, like minigrids and stand-alone solar home systems, to contribute to development.

Access to electricity is recognized as fundamental to development, and many efforts are under way across developing countries to scale up access, both in terms of providing basic supply and enabling people to move up through the energy tiers. However, it has become apparent that providing a connection to electricity, whether from a grid or off-grid source, does not automatically bring development benefits. If the electricity supply is of poor quality, it constrains productive activity by households and enterprises. Regardless of quality, if electricity is too expensive, consumers will not be able to afford connections, or subsequent payments for service. Equally, even in the presence of good-quality, reasonably priced

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Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.

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electricity, if there is not adequate, stable demand from potential users, then energy-service providers will not be able to sustain a viable business and the electrification effort will likely fail.

Building on this understanding of electricity supply and demand, we argue that the relationship between electricity access and development is two-way. Development cannot be accelerated without access to electricity. But financially self-sustaining electricity access initiatives cannot be supported without successful development that underpins strong and sustained demand for electricity services.

We propose an approach to closing the electricity access gap that is based on three clear strategies.

Understand electricity demand from the bottom up. Traditional electricity planning has relied on top-down projections of future demand based on extrapolations of historic demand patterns, or on forecasts of future economic growth. These methods do not take into account the very different levels of need among consumers; nor do they factor in the millions of consumers not yet represented in the connected load. Bottom-up demand forecasting, based on consumer surveys or on energy end-use modeling, allows a disaggregated perspective that facilitates appropriate technology choices and least-cost development that matches the variations in electricity service needs across different consumer segments.

Link electricity access with local development efforts. There is an urgent need to avoid the "vicious cycle of underdevelopment," in which areas with low levels of economic development have low levels of demand for electricity, which makes them unattractive to electricity service providers. The lack of access to electricity, in turn, perpetuates the lack of economic development in these areas. Energy planners need to understand the enabling role of electricity if they are to design access initiatives that promote development objectives. And electricity planners need to consider how electricity impacts the livelihoods of the poor and how the poor value and use electricity in their decision-making processes. If access initiatives are linked more closely with development projects, with energy planners tapping into the expertise of other development actors, finance organizations, and community groups, then synergies can be exploited and additional funds leveraged to ensure that electricity access and development become mutually reinforcing endeavors.

Build good governance in electricity access. Good governance is concerned with issues of affordability and with the quality and reliability of electricity services. Governments are familiar with the affordability challenge and have traditionally responded with subsidies, either to service providers or directly to consumers. While the need for subsidies will remain, governments can also play other roles to facilitate more affordable electricity. Options include encouraging emerging end-user finance models, such as pay-as-you-go, streamlining policies and regulations for distributed generation options to reduce their costs and encourage greater involvement on the part of private lenders, and reducing trade barriers on imported alternative/high efficiency electrical products. Addressing reliability and quality-of-supply issues will call for improvements in the technical characteristics of electricity supply systems as well as strong and effective structures for accountability in electricity service delivery.

These three components of our proposed approach are all driven by the belief that electricity planning must be more responsive to consumer demand, and that "demand" should be understood to mean both conventional demand—defined in terms of connected load—and latent demand, which may be defined as the unmet demand of potential customers who currently lack physical connections to electricity supply, or cannot afford to pay for it, or do not have the development opportunities necessary to make productive use of it.

While the term "energy access" covers a range of services, including access to electricity and various fuels for cooking and heating, this paper focuses exclusively on access to electricity. Our central concern is how national and subnational electricity planning processes can be oriented to encourage initiatives that yield both access to electricity and sustainable development outcomes.

The paper is intended primarily for electricity planners, policymakers, and electricity-service providers in developing countries. These actors are working to close the electricity access gap in an energy-development landscape that is rapidly evolving. It is our hope that they can draw on this paper for guidance. To this end, we recommend a number of interventions in each of the three areas identified by this paper as critical for implementing effective electricity access initiatives. We also suggest other key stakeholders who should be engaged in the process of change. Our recommendations are summarized here; a more complete list can be found at the end of this paper.

PROMOTING THE BOTTOM-UP ESTIMATION OF ELECTRICITY DEMAND

- Build databases of electricity end-use equipment and services in different consumer segments.
- Share market information and data on consumer demand.
- Encourage the role of distributed generation options and include them in national plans.

ESTABLISHING LINKAGES BETWEEN ELECTRICITY ACCESS AND OTHER DEVELOPMENT SECTORS

- Harmonize national policies for electricity and other development sectors.
- Build demand for electricity services by supporting development in other sectors.
- Compile information on sector-specific benefits of electrification and provide to local enterprises, development agencies, and so on.
- Monitor impacts of electricity access on other development sectors and vice versa.

BUILDING GOOD GOVERNANCE PRINCIPLES (AFFORDABILITY, RELIABILITY, AND QUALITY-OF-SUPPLY CONSIDERATIONS) INTO ELECTRICITY ACCESS INITIATIVES

- Establish a transparent and participatory electricity planning process.
- Set up structures for transparency and accountability in electricity service delivery.
- Engage the help of nontraditional regulators (civil society groups, community groups) in monitoring and evaluating the performance of utilities and energy-service providers.
- Monitor price support mechanisms to ensure they reach their target groups and costs do not exceed benefits.
- Build demand for electricity services by supporting development in other sectors.
- Encourage research and deployment of emerging technologies that support innovative financing models for consumers.
- Work to reduce transaction costs in the off-grid sector.
- Build capacity in rural communities to operate and maintain off-grid systems.
- Build capacity of local financial institutions to better understand emerging electricity finance models.

INTRODUCTION

As the role of energy access in development has become better understood, there is an increased focus on "energy for all" or the expansion of access to energy services into even the poorest and remotest areas. Electricity, in particular, is a critical input to increase the productivity of labor. The availability of machinery, tools, and appliances powered by electricity promotes the development of income-generating activities such as agro-processing, welding, construction, and small-scale manufacturing. Access to electricity also facilitates more efficient use of household time (Dieden et al. 2007). Community services such as health, education, and water provision all depend, in different ways, on the availability of energy. Nonetheless, estimates indicate that more than 1 billion people in developing countries are served by health facilities without access to electricity and over 291 million children go to schools without electricity (Practical Action 2013).

Numerous efforts are under way at international and national levels to expand the supply of clean, affordable, and reliable electricity services to those without access. In 2013, the United Nations launched its Sustainable Energy for All (SE4ALL) initiative. A key goal of this global initiative is the attainment of universal access to modern energy services, including electricity services, by 2030. At the national level, governments in developing countries are developing ambitious targets for the attainment of universal access in line with these global objectives. As governments press to achieve these targets, they will need to ask the right questions and rethink some of their existing strategies for closing the access gap.

Objective and Scope

The objective of this paper is to explore some of the key issues that policymakers and planners will have to consider as they work to close the electricity access gap in an energy-development landscape that is rapidly evolving.

The term "energy access" covers a range of services including access to electricity and various fuels for cooking and heating. This paper, however, focuses exclusively on one dimension, namely, access to electricity. It is concerned with how national and subnational electricity planning processes can be oriented to encourage initiatives that yield both access to electricity and sustainable development outcomes. It is our hope that electricity planners and policymakers in developing countries can draw on this paper for guidance.

Study Approach

This paper draws extensively on a review of the existing literature. We identify three elements we believe to be essential in developing successful approaches to addressing the electricity access gap (Figure 1):

- A disaggregated understanding of bottom-up demand estimation, based on the energy services that can be derived from electricity access.
- The creation of synergies between electricity access and broader development strategies.
- The promotion of good governance principles in the institutions and arrangements governing electricity access.

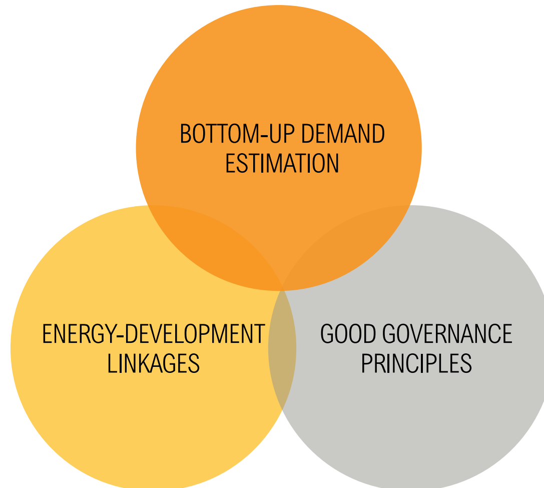
The paper comprises three major sections, addressing in turn each of the elements identified above as critical to closing the electricity access gap. A summary of recommendations for policymakers and planners is provided at the end of the document. The recommendations highlight key areas of intervention where policymakers and planners can move forward in their countries the propositions presented in this paper. The summary of recommendations can also serve as a quick reference guide or be used to steer stakeholder discussions on the issues discussed in this paper.

Context: Defining the Electricity Access Gap

We set the stage with a discussion of the electricity access gap, as a shared understanding is central to our discussions. National agencies and development organizations have long measured and/or defined electricity access by the physical connection of households to electricity, the nearby presence of an electric pole, or the proximity of households/communities to existing grid transmission lines. While these types of definitions and assessments of access have been useful for survey purposes, they have not provided truly accurate insight into the status of electrification in many developing countries. They have four major flaws:

- Analyses based on household-level electricity connections fail to capture access to electricity for productive uses and for social services such as health and education (Practical Action 2014).
- Definitions of access based on measuring physical connections to electricity tend to imply that physical access is equivalent to access to the services and associated benefits of electrification.

Figure 1 | **Key Elements of Improving Access to Electricity Services**



Source: WRI

- Definitions based on connection to the grid or proximity to grid lines fail to capture the contribution to electricity access made by decentralized options such as stand-alone home systems and minigrids.
- Connections-based definitions of access fail to capture the large numbers of people who are physically connected to electricity but receive insufficient and unreliable supply (Angelou et al. 2013; Bhatia and Angelou 2015).

The World Bank Energy Sector Management Assistance Program (ESMAP) has attempted to address these flaws in the conventional definitions of electricity access with its Multi-tier Framework for defining and measuring levels of energy access. The framework as it pertains to electricity access is presented in Table 1 below.

Under the framework, electricity access is measured across five tiers. Each tier reflects a specific level of performance of an electricity supply system, defined by seven attributes. According to the framework, electricity access is the ability to obtain electricity "that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy and safe for all required applications across households, productive enterprises and community institutions" (IEA and World Bank 2015).

Table 1 | **The ESMAP Multi-tier Framework for Electricity Access**

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Typical applications of household electricity services		None	Radio, task lighting	Tier 1 + General lighting, TV, light office needs	Tier 2+ Air cooling, food processing, task-oriented food preparation	Tier 3+ Refrigeration, water heating, pumps, expanded food preparation	Tier 4+ Air conditioning, space heating
Indicative technologies*			Solar lantern Rechargeable batteries Home system Minigrid Grid	Rechargeable batteries Home system Minigrids Grid	Home system Minigrids Grid	Home system Minigrids Grid	Home system Minigrids Grid
Attribute 1: Peak capacity	Power		V. low power min 5 W	Low power min 70 W	Medium power min 200 W	High power min 800 W	V. high power min 2 kW
	Daily capacity		Min 20 Wh	Min 270 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
Attribute 2: Duration	Hours per day		Min 4 hrs		Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 2 hrs		Min 2 hrs	Min 4 hrs	Min 4 hrs
Attribute 3: Reliability					Max 3 disruptions **per day**	Max 7 disruptions **per week**	Max 3 disruptions **per week** of total duration <2 hrs
Attribute 4: Quality					Voltage problems do not prevent the use of desired appliances.		
Attribute 5: Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income.		
Attribute 6: Legality					Bill is paid to the utility/prepaid card seller or authorized representative.		
Attribute 7: Health and safety					Absence of past accidents, low perception of risk in the future		

Source: IEA and World Bank 2015
*Indicative technologies added by authors

This definition of electricity access represents a radical departure from the conventional binary metrics discussed above and offers a number of improvements.

- The framework draws attention not just to the 1.1 billion households lacking access to electricity connections but also to the millions of households, businesses, and community institutions that receive poor and inadequate electricity services. Unreliable power supply curtails the benefits of electricity access (Banerjee et al. 2015; Rao, Agarwal, and Wood 2016). In India, about 20 million households receive less than four hours of electricity per day (Climate Group 2015). In Africa, 40 million people in countries that rank in the top 10 in terms of electricity access challenges do not have access to reliable electricity supply (BNEF 2016). Local businesses in Africa increasingly cite the lack of access to adequate and reliable electricity as the most significant constraint to their effective operation—ahead of red tape, financing, and corruption (IEA 2014). Improving the reliability of electricity supply will be key to addressing the electricity access gap and thereby promoting socioeconomic development in these areas.
- The framework also draws attention to the diversity of supply options that can and should be harnessed to address electricity needs. Whereas, historically, there has been a disproportionate focus on extending the central grid to provide electricity, the framework draws attention to the potential complementary role of distributed options such as stand-alone systems and minigrids. The International Energy Agency (IEA) has projected that attaining universal access to electricity by 2030 will require the adoption of approaches that integrate both conventional grid and distributed generation options. It is estimated that nearly half (45.5 percent) of rural areas lacking electricity will be connected by minigrids, and a quarter (24.5 percent) of rural areas will rely on small, stand-alone solutions

such as solar home systems for first-time electricity access by 2030 (IEA 2013).

- The definition of electricity access provided by the framework considers energy applications across households, productive activities, and community uses.
- Though not explicitly included in the framework, discussions of the role of energy efficiency in access are also emerging around the Multi-tier Framework for access. This will be discussed further in the paper.

In the coming sections, we draw on these emerging insights from the Multi-tier Framework to demonstrate why a bottom-up understanding of electricity demand in electricity planning, electricity-development linkages, and good governance principles (relating to affordability, quality, and reliability of supply) are key to implementing successful electricity access initiatives in developing countries.

SECTION 1: PLANNING: UNDERSTANDING ELECTRICITY DEMAND FROM THE BOTTOM UP

> A bottom-up understanding of electricity demand can promote a targeted and cost-effective response to electricity service needs that draws on a mix of technology options to meet the differential needs of various consumer segments.

1.1 Conventional Approaches to Forecasting Electricity Demand

Electricity planning begins with an understanding of electricity demand.[1] Electricity planning entails three key processes: load or demand forecasting, the development of assumptions on the costs of investing in specific technological options for meeting demand, and a choice among the technological options. Conventional electricity planning uses various techniques when estimating demand (Dharmadhikary and Bhalerao 2015). A complete assessment of these techniques is beyond the scope of this paper. However, two approaches that have been widely used in developing countries are worth mentioning here—forecasting based on *trend analysis* and forecasting based on *GDP growth*.

In trend forecasting, linear and nonlinear regression models are used to extrapolate future demand from historical electricity usage patterns. Even though this approach is relatively simple it tends to be rife with inaccuracies. The model fails to capture factors that are likely to impact electricity demand, such as changes in economic and demographic parameters. The nature and choice of historical data also tends to impact the accuracy of these analyses. Highly variable historical data make it difficult to derive a regression with a good fit. The length of the historical time frame used in the analysis may also impact the results of the demand forecast (Simpson and Gotham 2014).

GDP growth-based forecasts develop medium- to long-term demand forecasts by multiplying medium- to long-term forecasts of GDP growth by electricity elasticity.[2] These demand forecasts, in turn, inform decisions on the generating capacity that will be needed to satisfy demand over the planning period under consideration. This approach has been widely used by planners in many developing countries. India's federal Planning Commission used this approach to develop the country's Integrated Energy Plan. The plan, which projects India's energy and electricity requirements through the years 2031–32, provides scenarios of energy demand given GDP growth rates of 8 percent and 9 percent under two assumptions: falling electricity elasticities and no change in elasticities (Government of India Planning Commission 2006). Generally, electricity planning based on GDP growth forecasts has led to electricity plans that focus on a limited set of technological options (usually large-scale grid-based generation technologies) to meet demand (Greacen, von Hippel, and Bill 2013; Reddy 1991).

Persistent gaps in electricity access and concerns that electrification initiatives will fail to deliver socioeconomic benefits to consumers are raising questions about the conventional planning process (Reddy 1991). Top-down models often lack a normative component, and they tend to focus on what "would be" the electricity demand rather than what "should be" (Dharmadhikary and Bhalerao 2015). As a result, people who, historically, have been left out of electricity access planning continue to be left out. Today, around 1.1 billion people lack access to electricity services that satisfy basic needs in countries where conventional planning has been used for years. In this paper, we propose a shift to an electricity-planning regime that works from the bottom up. The approach draws on a diverse pool of technologies to provide electricity access (including grid, distributed generation, and energy efficiency) and ensures that electricity access brings tangible development benefits to consumers. Bottom-up demand forecasting offers a way forward.

1.2 Toward Bottom-Up Demand Forecasting

Bottom-up demand forecasting approaches are alternatives to conventional top-down approaches. They develop demand forecasts that are based on surveys or models using information on actual and desired patterns of electricity consumption among consumers. The results are summed across the entire group of consumers under consideration. The approach is effective in providing a more disaggregated understanding of demand across different consumer segments (Simpson and Gotham 2014).

A bottom-up approach is complementary to the Multi-tier Framework for electricity access, which also focuses on different levels of access based on differentiated energy needs. Differential electricity service needs may not always call for grid electricity. Access at different tiers can be satisfied by a variety of options. For instance, some remote rural communities need only lower-tier levels of electricity service in the early stages of access and development. It might make better economic sense to implement alternative options such as home systems or small-scale minigrids, coupled with energy-efficient appliances, rather than to pursue grid extension, which may be comparatively expensive to implement in rural locations. Also, where demand for electricity for specific end uses can be met through other means (for example, a solar water pump for agricultural irrigation), the demand for grid electricity can be reduced. In order to permit the adoption of these alternative options, however, demand forecasting studies must permit a disaggregated understanding of the different energy-service needs of different consumer segments. Bottom-up demand forecasting allows such disaggregation.

Bottom-up demand forecasting may be *survey-based* or may be derived from *end-use models*.

Survey-Based Forecasting

In survey-based forecasting, electricity planners or service providers project future demand based on information on perceived changes in electricity demand over time obtained from a group of consumers through direct customer surveys or public announcements. Survey-based forecasting usually focuses on the largest electricity consumers who have the greatest impact on electricity demand trends; possible changes in their demand patterns represent the greatest uncertainty for service providers (Simpson and Gotham 2014). However, in the context of expanding access to electricity, survey-based forecasting, if adopted by electricity planners, will also have to capture unserved and underserved communities. Information from these communities will ensure that their demand for electricity services is equally understood and factored into the planning process. In India, the Solar Electric Light Company (SELCO) is using consumer surveys to develop electricity access solutions that are specifically tailored to respond to unique consumer needs. Details of the program are presented in Box 1 below.

End-Use Modeling

End-use modeling is a second bottom-up approach to forecasting electricity demand. Electricity planners and service providers quantify electricity demand on the basis of consumers' present and projected electricity end-use patterns (Dharmadhikary and Bhalerao 2015; Greacen, von Hippel, and Bill 2013). The approach relies on the availability of data on energy-use patterns of a wide range of consumers, including household, commercial, industrial, and institutional consumers. Electricity planners collect data on the appliances and electrical equipment used by different consumer segments. Electricity consumption is then categorized according to the desired services or end uses, such as lighting, refrigeration, space heating, and cooling (Greacen, von Hippel, and Bill 2013; Simpson and Gotham 2014, 4). In this way, electricity planners are able to understand the demand profiles of different consumers, disaggregated by the end uses of electricity. Planners are also able to capture across different consumer categories unmet demand that results from either insufficient or unreliable supply.

End-use models are based on assumptions that are easy to follow. As new data become available, electricity planners can revise the models to reflect up-to-date forecasts of energy and peak power demand. The end-use approach is also useful for capturing the impacts of energy efficiency and demand-side management options. Electricity planners can factor these parameters into demand forecasting and subsequent generation capacity planning (Greacen, von Hippel, and Bill 2013, 10). A practical example of a planning framework based on the end-use approach is presented in Box 2.

1.3 The Value of Bottom-Up Demand Forecasting

Because bottom-up demand forecasting approaches use granular data on consumer demand, they facilitate a better understanding of the variations in electricity service needs across different consumer segments. Differences in electricity needs among different settlement types—urban, rural, and informal—can also be understood using these approaches (IIED and TERI 2014). Energy planners and service providers can provide targeted energy services. They can also consider important questions early in the planning process: What mix of electricity technology options will be most appropriate for meeting consumer demand? How do we account for changes or growth in demand over time?

Box 1 | SELCO's Ecosystem Analysis Approach

SELCO India has developed a bottom-up, demand-driven approach called "ecosystem analysis" for expanding electricity access. This approach involves first developing an in-depth understanding of the energy needs of a specified region (usually a district). This is done through a combination of household surveys, focus group discussions, and interviews with members of the community, local businesses at the village level, and key representatives from local institutions at the block level. Information captured through these surveys includes demographic data, appliance usage, banking access, industrial development, current electrification scenarios, fuel consumption, health and education facilities, mobile phone networks, and available local subsidies for energy.

SELCO then develops a customized intervention roadmap at the household, community, and productive activities levels using the following parameters: finance, capacity building, infrastructure, technology, and policy and regulation. This approach recognizes the diverse needs of different communities and consumer segments and also helps identify key on-the-ground actors (e.g., government agencies, microenterprises, technicians, rural banks, and cooperatives). The aim is to understand their respective roles, and gauge local capacity (e.g., ability to access loans, awareness of clean energy solutions, availability of LED and CFL bulbs, etc.) in order to determine whether the ecosystem is receptive to electricity access solutions.

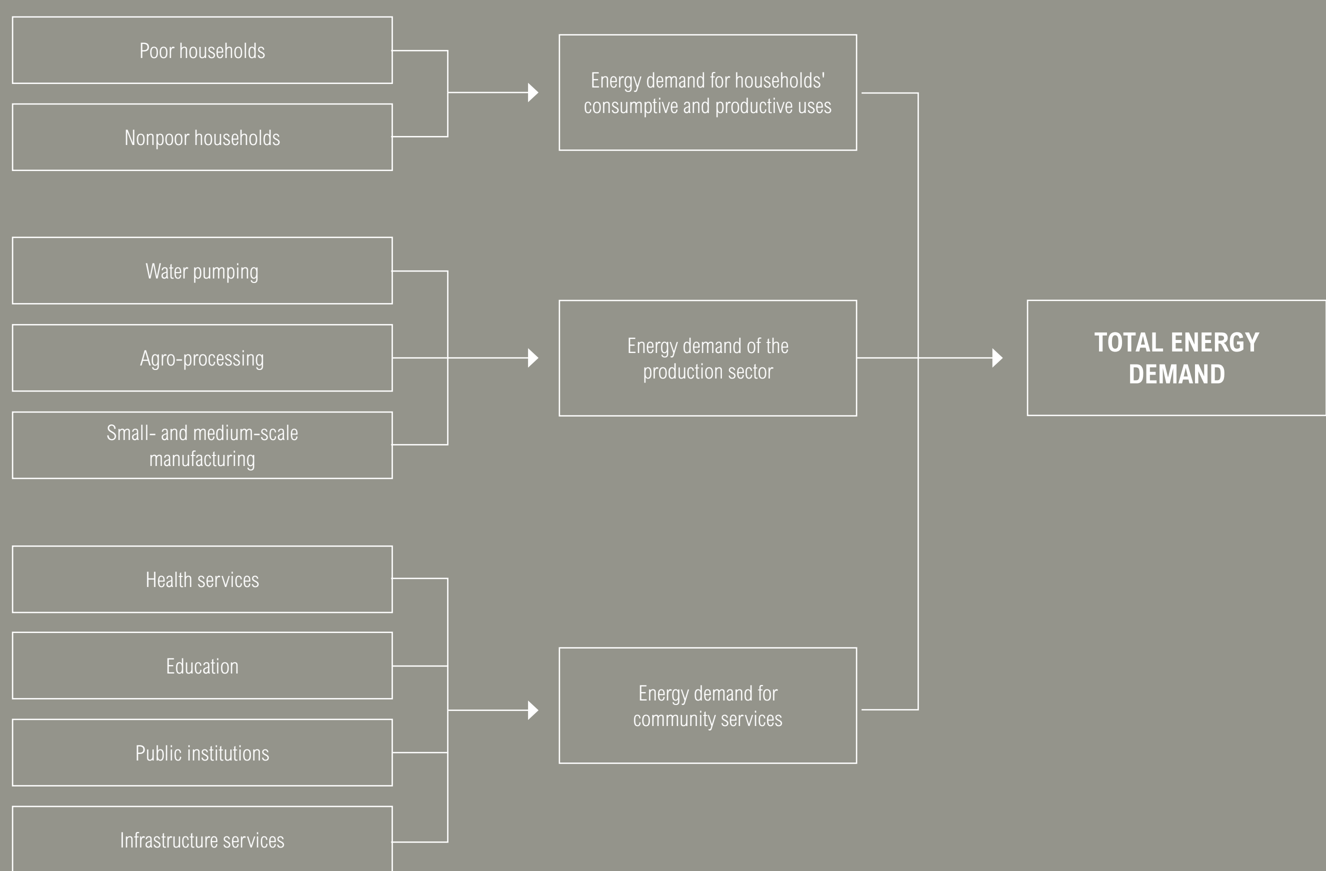
SELCO has developed a number of solutions for districts it has studied in the states of Orissa and Uttar Pradesh. They include

- developing pay-as-you-go repayment methods for solar home system purchases (possible thanks to widespread mobile phone penetration);
- converting existing diesel-energy entrepreneurs to decentralized renewable energy (DRE) retailers,
- using DRE technologies to floodlight forest fringe areas and prevent human-animal conflict; and
- developing the capacity of self-help groups to operate and manage RE systems (WWF India and SELCO Foundation 2015).

SELCO is also using its experience to develop unique products and solutions such as solar-powered sewing machines, solar-powered food driers, and DC refrigerators to meet specific end-use needs in particular areas or communities (SELCO Foundation 2015). In Lakhimpur, Uttar Pradesh, for instance, the foundation has suggested the deployment of solar-based water-purification technologies to mitigate the effects of drinking water contamination caused by indiscriminate fertilizer use (WWF India and SELCO Foundation 2015).

Box 2 | The Asian Development Bank's Sustainable Energy Access Framework

The Asian Development Bank has developed the Sustainable Energy Access Planning (SEAP) framework as an alternative to traditional energy access planning approaches used in developing countries in the Asia-Pacific region. The framework is intended to facilitate a more comprehensive approach to providing electricity access, one that responds better to the energy-service needs of both the poor and nonpoor in the region. The framework draws on the end-use approach to assess demand. The focus is on the interrelationship between energy demand and the end-use technologies utilized by consumers to meet that demand. Total energy demand is determined by summing end-use demand projections across the entire range of consumer segments. At the household level, end use–based demand projections span both the consumptive and productive uses of electricity in both poor and nonpoor households. In the production sector, energy demand projections are derived from assessments of both small- and medium-scale manufacturing sectors, agro-processing, and water pumping. The energy demand from community services is likewise derived from a summation of end use-based estimates across health services, education, public institutions, and infrastructure services (Shrestha and Acharya 2015).



Bottom-up demand forecasting can enable energy planners to develop least-cost approaches to meeting consumer demand, while keeping environmental and social impacts in mind. A practical example of this benefit is seen in the application of Amulya Reddy's DEFENDUS (Development Focused End-Use Oriented) planning approach to the Indian state of Karnataka. The DEFENDUS method promotes a holistic approach to electricity access that draws on a mix of energy efficiency, decentralized generation sources, and centralized sources to meet access goals. This approach suggests that bottom-up planning can result in a better mix of technology options that respond to the electricity service needs of those who need them in a more cost-effective way than can conventional planning approaches (see Box 3).

Because bottom-up demand forecasting permits different supply options to be considered under different energy-demand scenarios, it can provide early pointers to the policy, planning, and regulatory issues that may arise as countries shift their focus to more diverse options for addressing the access gap. For instance, in areas where electricity planners foresee a potential complementary role for distributed generation options, based on estimated demand profiles, they can begin to think about the policy and regulatory provisions that might be needed to accommodate these options, in addition to the conventional grid.

Finally, bottom-up demand forecasting approaches tend to be participatory, engaging consumers directly in demand assessments. These assessments are not made in closed processes by energy experts, ministries, and utilities; they involve a wider cast of actors, including the consumers of electricity services. The CHOICES program in South Africa, for example, was designed to "understand and capture nuances of community energy needs and preferences across a target population in South Africa" (IIED and TERI 2014, 1). The program was guided by a community-centered approach. Target communities across the rural, urban, and informal settlement spectrum in South Africa's Eastern Cape were invited to participate in "energy options" workshops. These workshops were structured to facilitate an understanding of consumer needs and priorities as well as the willingness of communities to pay for the satisfaction of these needs. The workshops revealed gaping differences in energy needs across and even within urban, rural, and informal settlements. By engaging consumers in these dialogues, the program raised awareness of and promoted buy-in for locally specific energy solutions (IIED and TERI 2014).

Box 3 | DEFENDUS Planning in the Indian State of Karnataka

In 1987, the Indian state of Karnataka developed its Long-Range Plan for Power Projects (LRPPP) for the period 1987–2000. The power plan was developed using the conventional approach to electricity planning; the scale of supply was determined by projected GDP growth over the planning time frame. According to the plan, an investment of US$17.438 billion would be needed to meet the state's energy and power requirements of approximately 48 TWh and 9 GW, respectively, by the year 2000. The investment would go into building transmission lines, coal transportation facilities, and centralized power generation facilities (Reddy 1991).

Using DEFENDUS, Amulya Reddy demonstrated that a planning approach with people-focused development as its ultimate goal could facilitate a more cost-effective response to addressing the demand gap while also responding to the electricity service needs of the poor.

The approach entailed three key steps:

- An assessment of consumers' electricity end uses.
- An assessment of the technological options that could be used to meet these end uses and enable a more efficient utilization of energy.
- A least-cost approach to identifying the appropriate supply mix needed to meet electricity needs while keeping environmental considerations in mind.

The approach focused on providing electricity to households and supporting employment-generating activities. The energy and power requirements for the state of Karnataka determined through the DEFENDUS approach were lower by 38 percent and 42 percent, respectively, than the requirements determined through conventional planning. Efficiency and substitution measures alone (such as substituting inefficient motors and incandescent bulbs with more efficient ones, substituting electric water heater heaters with solar water heaters, and retrofitting irrigation pumps) could result in a 41 percent reduction in overall demand (Reddy 1991).

It was proposed that this reduced demand be met with a specific mix of technologies: 40 percent to be efficiency improvements and substitution, 40 percent decentralized technologies, and 20 percent centralized generation. In contrast, the conventional power planning approach had proposed that the projected demand in the LRPPP be met with a mix of large-scale centralized technologies only (nuclear, coal-based thermal generation, and large hydroelectric power plants).

1.4. The Role of Energy Efficiency in Expanding Electricity Access

Approaches to demand estimation based on end-use data permit energy planners and service providers to incorporate energy efficiency and demand-side management into forecasting and subsequent generation-capacity planning. Efficiency and demand-side management considerations are important because they enable consumers do more with less electricity. This is of critical importance because most people without electricity access live in electricity-constrained environments.

Supply-Side Efficiency

Poor supply-side efficiency can result in significant depletion of the electricity that is ultimately available to end consumers and can lead to higher electricity costs. Unfortunately, developing countries with strained electricity budgets usually invest in power plants with very low efficiencies due to the generally lower upfront costs of such options (IEA 2014). Old and poorly maintained transmission and distribution (T&D) infrastructure may also result in significant transmission and distribution losses, further reducing the electricity available to consumers. In sub-Saharan Africa, T&D losses average about 18 percent; this is more than double the global average. Individual countries report T&D losses of over 20 percent (IEA 2014). These high loss percentages impede the ability of utilities to provide sufficient and reliable supplies of electricity and can lead to significantly higher electricity prices. In Africa, for instance, poor supply-side efficiency is said to have the potential to increase average electricity prices by up to $50–$80 per MWh (IEA 2014). Technical losses can be further compounded by commercial losses caused by low metering efficiency, theft and pilferage, billing errors, and inefficient tariff collection. Utilities lose revenue and are unable to properly maintain infrastructure and provide reliable electricity services to consumers.

Demand-Side Efficiency

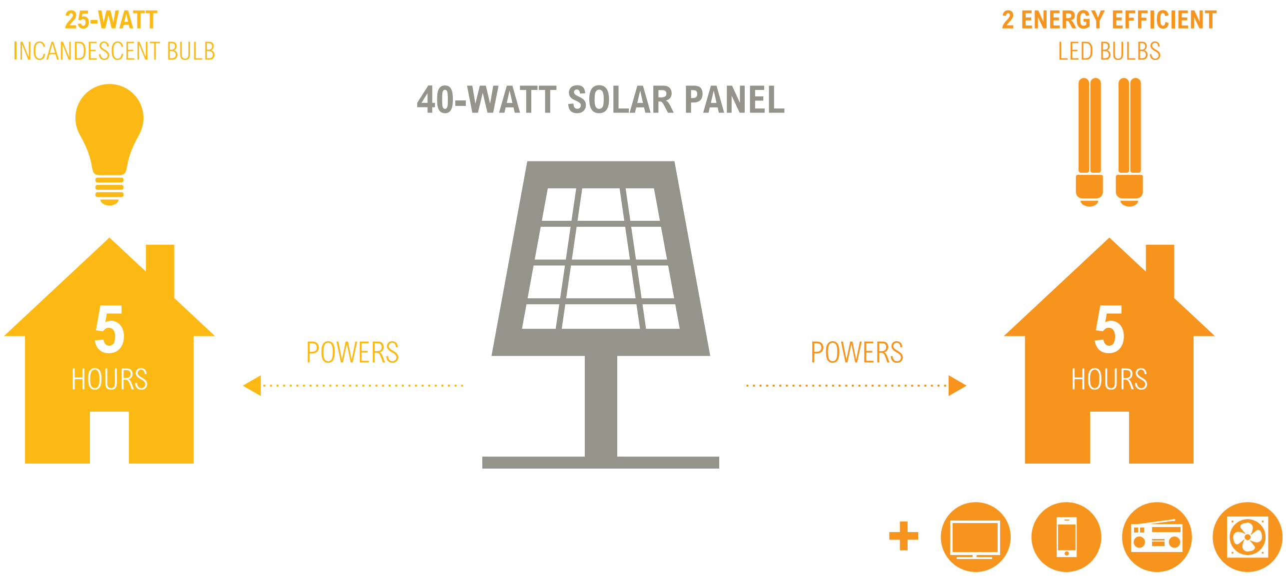
Demand-side efficiency, for both grid-connected and off-grid consumers, can also play a role in closing the overall supply gaps that confront electricity planners and service providers. Demand-side measures focus on reducing the overall electricity demand of consumers; such measures are not intended to reduce the benefits that consumers derive from electricity but instead to enable them to do more with less. The use of higher efficiency end-use appliances can reduce overall peak loads. National utilities and energy-service providers will be able to save on investments in new generation capacity if peak loads can be held down. For instance, the government of Ghana, thanks to its appliance-efficiency standards and energy-labeling program, is expected to save US$840 million that would otherwise have been required for investment in developing new generation capacity by 2020 (CLASP 2013).[3] From a planning perspective, these savings can be invested in other areas in need of attention. For example, planners could draw on these funds to develop much-needed databases on bottom-up electricity demand.

Demand-side efficiency is also relevant in the off-grid context. Whether power is provided from home systems or microgrids, energy efficiency enables consumers to derive greater benefit from the electricity supplied. For example, whereas a 40-watt solar panel can provide five hours of lighting when used in conjunction with a 25-watt incandescent bulb, the same panel could be used to provide five hours of lighting for two LED lights and simultaneously power a color television, fan, mobile phone charger, and radio for up to three hours (Global LEAP 2016) (see Figure 2).

The Global Lighting and Energy Access Partnership (Global LEAP) is working to enhance the efficiency of off-grid DC appliances powered by off-grid generation systems such as home systems and microgrids. The program is building sustainable markets for superefficient off-grid appliances such as lamps, televisions, and light bulbs. These efforts could be further extended to include AC appliances.

Demand-side management is of great importance in the productive use sector. Many motor-based appliances that power livelihood activities, such as sewing machines, small power looms, and milling machines, rely on highly inefficient AC motors. Energy planners can consider programs to improve the efficiency of AC motors or retrofit them with DC motors. These efficiency gains can benefit the bottom lines of productive-use sectors.[4] A solid understanding of electricity end uses is key to promoting demand-side efficiency. Bottom-up energy demand assessments can provide the necessary insights about energy end uses across the different tiers of electricity access and consumer segments. This in turn can support planning decisions regarding where to target demand-side management efforts in the household, productive, and commercial sectors.

Figure 2 | **The Benefits of Demand-Side Efficiency**



Source: WRI, based on information from Global LEAP 2016

1.5 The Role of Government in Promoting Bottom-Up Demand Forecasting

The bottom-up approaches described so far are data intensive. Surveying large samples of consumers will require significant financial commitments. Likewise, building extensive but dependable databases of disaggregated electricity end uses is likely to involve significant financial costs. However, because these approaches can promote more effective power planning and save money over the longer term, developing country governments at various levels (national, state, provincial, and local) should consider exploring ways to circumvent the cost prohibitions. For instance, in some countries, bottom-up electricity demand assessments can be built into periodic national and subnational surveys such as censuses or regular biannual demographic surveys. Electricity planners could also explore the role of widely available mobile technology to collect and validate data on energy use dynamics.

Nongovernmental partners might also be enlisted. Private energy-service providers are collecting data on electricity use patterns as part of their regular market operations and might be willing to share their data in the context of public-private partnerships (PPPs). In some countries, nongovernmental organizations (NGOs) are collecting data on energy use patterns: In Uganda, the local World Wildlife Fund (WWF) office has collected baseline data on energy-use patterns and demand in households, small and medium-sized enterprises, and industries in the Kasese district. The data serve as an input to the WWF's Champion District Approach to Clean Energy Access. Data on access to different forms of energy, including electricity, expenditures on energy, income profiles, and energy-use patterns are used to determine the most appropriate ways to meet consumer demand in the district (WWF Uganda 2013). If energy-service providers and NGOs are willing to share the information they collect, national planners can collaborate with them to consolidate these data and incorporate them into national plans. Governments can also explore the potential role of international development assistance in supporting the development of databases on electricity demand.

To summarize, bottom-up demand estimation can enable energy planners to select the most appropriate technological options for meeting demand. Because the approach is based on an understanding of how different consumers use electricity, planners can be challenged to think beyond the delivery of kilowatt-hours and focus on the energy services that consumers receive from electricity access. In the next section we explore why such a reorientation in energy planning is necessary to attain broader development goals and ensure the long-term sustainability of electricity access initiatives.

SECTION 2: LINKING ELECTRICITY ACCESS WITH LOCAL DEVELOPMENT EFFORTS

The relationship between electricity access and development is two-way. Development cannot be accelerated without access to electricity. Likewise, financially self-sustaining electricity access initiatives cannot be supported without successful development that underpins strong and sustained demand for electricity services.

The second element of our suggested approach to closing the electricity access gap is the exploitation of synergies between electricity access initiatives and development goals. There is a general consensus that access to modern forms of energy such as electricity can bring several development benefits (see Barnes and Floor 1996; Cabraal, Barnes, and Agarwal 2005; Modi et al. 2005). But the mere provision of electricity does not guarantee such benefits. Electricity is an enabling factor, which works in concert with other factors to bring development gains to consumers (Dieden et al. 2007). For instance, the provision of electricity connections does not necessarily result in better educational outcomes unless schools, teachers, and study materials are also made available. Similar examples apply to health, agriculture, and other sectors. In some cases, public programs such as national electrification schemes have succeeded in bringing electricity for basic services such as lighting and powering small appliances to communities without access but have failed to catalyze economic development in the target communities. Sometimes failure has occurred even after the development of extensive distribution networks that can significantly drain the resources of national utilities (OAS 1988; ESMAP 2008).

Electricity planners need to understand the enabling role of electricity if they are to design access initiatives that promote development objectives. Electricity planners need to consider how electricity impacts the livelihoods of the poor and how the poor value and use electricity in their decision-making processes (DfID 2002; UN-Energy 2005). Only by doing so can planners develop strategies for achieving electricity access that link electricity connections to the attainment of salient development goals (Cabraal, Barnes, and Agarwal 2005). Within national and subnational governments, this calls for close cooperation among policymakers and decision-makers in the electricity sector and other developmental sectors like health and education. Cooperation and harmonized goals could catalyze a shift in the direction of conventional electrification efforts; practitioners will be obliged to look beyond the provision of specific electrification technologies to carefully consider the impacts of their efforts on local development priorities (ESMAP 2008).

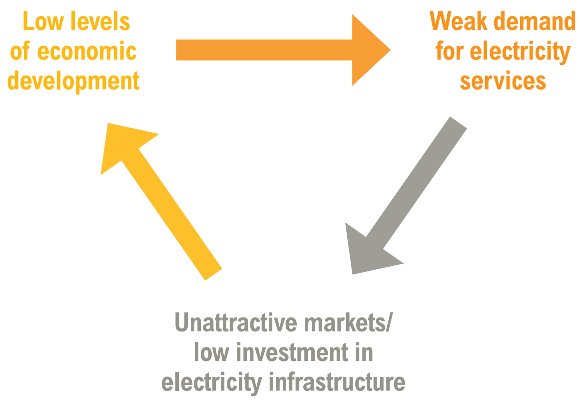
2.1 Scaling Demand for Electricity through Local Development

The synergies between electricity access and development work in both directions. Just as electricity access is a necessary component of successful development, so too is development a necessary condition to sustain successful electricity access initiatives.

In conventional terms, the need for electricity services is not synonymous with demand for electricity services. Although there may be a clear and urgent need for electricity services, this need will not be translated into demand in the market if consumers are unable to pay for them. Their need will not be reflected in electric loads and will not be factored into conventional demand projections and plans for expanded electricity access. Consumers' willingness and ability to pay for services is thus a key determinant of the success of electricity access initiatives, although other factors are involved. In this section of the paper, we use the term "demand" to capture both the demonstrated need for electricity services that is manifested in connected loads as well as the latent need for electricity that is not yet manifested in connected loads.

Without sufficient demand, efforts to provide electricity services to those without access may not be economically viable. Private energy-service providers, especially, may not be able to access financing for electrification efforts in areas with weak demand. Project developers are hesitant to invest in regions where financially viable business models cannot be sustained or scaled-up due to poor demand. This situation can lead to the perpetuation of a vicious cycle of poverty and underdevelopment: areas with low levels of economic development have low levels of demand for electricity, which makes them unattractive to electricity service providers. The lack of access to electricity, in turn, perpetuates the lack of economic development in these areas (see Figure 3).

Figure 3 | **Electricity Access and the Vicious Cycle of Underdevelopment**



Source: WRI, based on information from OAS 1988

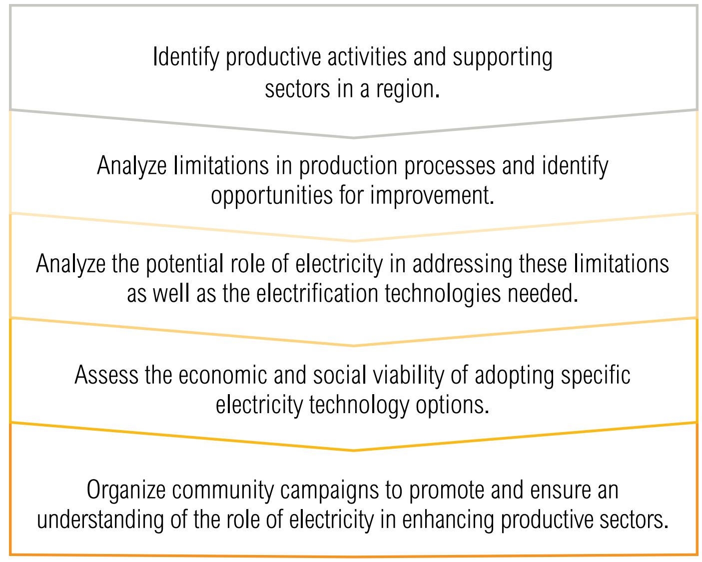
Electricity planners can demonstrate the existence of latent demand for electricity services and make electricity access more productive by working with actors in other development sectors to exploit the synergies between provision of energy services and socioeconomic development activities in the areas of, for example, water supply, health interventions, education, industrial growth, and construction (Barnes and Floor 1996).

The World Bank's ESMAP program has developed two approaches that can help guide energy planners seeking to establish these cross-sectoral linkages between electricity access initiatives and livelihood impacts. Energy planners can draw on these two approaches in a complementary fashion to build new demand for electricity services and making existing demand more visible.

The Systematic Approach to Establishing Energy-Development Linkages

The *systematic approach* enables energy planners to understand the expected gains that can be derived from introducing electricity into the production processes of goods and services in a specific context. The approach is useful in determining the latent demand for electricity services in various productive sectors. It involves five steps, shown in Figure 4.

Figure 4 | **The Systematic Approach to Establishing Energy-Development Linkages**



Source: WRI, based on information from ESMAP 2008

The Pragmatic Approach to Establishing Energy-Development Linkages

The second approach to establishing electricity-local development linkages is the *pragmatic approach*. This approach, often implemented in the form of multisector energy investment (MEC) projects, is "opportunistic" in that it taps into existing development activities as a means to scale electricity demand. Electricity access is provided or enhanced for already established projects/programs in other sectors (referred to as anchor sectors). Energy planners establish an interface between electrification activities and these sectoral development projects and programs with the aim of enhancing their productivity and bringing tangible benefits to local communities. The approach involves three steps, shown in Figure 5.

The two approaches for establishing electricity-development linkages are complementary. In Box 4 below we demonstrate how the approaches have been employed by Senegal's Rural Electrification Agency (ASER) to maximize the development impacts of the country's rural electrification program.

Figure 5 | The Pragmatic Approach to Establishing Energy-Development Linkages

IDENTIFY PRIORITY DEVELOPMENT SECTORS

Evaluate the potential for enhancing productivity within these sectors through electricity provision.

DETERMINE ELECTRIFICATION OPTIONS AND COSTS

Determine the costs of implementing various electrification options in response to identified sector needs.

ESTABLISH CONSENSUS AMONG STAKEHOLDERS

Establish consensus on the potential benefits of electricity in priority sectors and establish modalities for cooperation between electricity and other development sectors.

Source: WRI, based on information from ESMAP 2008

Box 4 | Senegal's Program to Maximize the Impacts of Rural Electrification

Using the *systematic approach*, Senegal's Rural Electrification Agency (ASER) brought together a group of experts specializing in different areas of rural productive activities. These experts were charged with identifying the specific processes or activities in rural productive sectors that were most likely to benefit from access to electricity. Thus, rather than a blanket recognition of the universal value of electricity to enhancing productive activities, ASER focused on understanding how different productive activities could benefit in their own specific ways from access to electricity. The agency incorporated the results of the initial assessments conducted by the team of experts into its Rural Electrification (RE) impact maximization program.

Based on the findings of the assessment, the RE program looked beyond the provision of energy services to institute other programs with the aim of ensuring that electrification efforts resulted in rural development benefits. For example, the program

- provided support for the development of agro-industrial processes in rural areas;
- provided support to ensure that relevant equipment needed for specific rural productive activities was available; and
- developed a database providing sector-specific information on the potential benefits of access to electricity for rural productive activities.

The *pragmatic approach* (MEC) focused on existing efforts that had very high development potential. Another team of experts led by ASER reviewed Senegal's national poverty reduction and public investment documents to identify five national development priorities: agriculture, rural irrigation, stockbreeding, fisheries, and rural cottage industries. They then identified key programs within these broad sectors, along with programs that could benefit substantially from electricity access. Once these programs had been identified, they were built into Senegal's approach to rural electrification, which is built around the awarding of concessions. Concessionaires are required to cooperate with the MECs that have been identified by the experts and lie within their concession areas. ASER has established rules stipulating the responsibilities of the energy-service provider, the MEC, and ASER in the arrangement. The anchor sector entity is generally responsible for developing the project and financing the equipment needed for its sector activities. The concessionaire, for its part, assumes responsibility for all electrical equipment. Concessionaires are able to apply for additional support from the Rural Electrification Fund to help them cover the extra costs of investments associated with providing electricity to the identified anchor sector program.

Note: Senegal's rural electrification approach hinges on the promotion of public-private partnerships for rural electrification through the allocation of concessions. The country is divided into 10 concession areas allotted to private operators through a competitive bidding process. Each concession has an average size of 5,000 to 10,000 customers. Concessions are awarded for a minimum of 25 years and are technology-neutral, permitting the concessionaire to decide on the most appropriate technology given the prevailing local circumstances and market structures. Concessionaires are also permitted to set tariffs at whatever levels they choose but not exceeding the maximum allowable tariff charges defined for that specific concession area. Concessions are usually awarded to the project developer who proposes to offer the maximum number of connections for the minimum grant amount. Selected concessionaires receive financial support from ASER in the form of subsidies, which can account for up to 80 percent of the total investment costs.

2.2. Tapping into Existing Local Expertise to Scale Electrification Efforts

Electricity planners can also tap into the expertise of other development sector actors, including NGOs, local development cooperatives, and community groups—particularly those that have been involved in implementing development programs in local communities. These actors might have existing local networks and associations that can facilitate more successful outcomes in electricity access initiatives (Rai et al. 2015).

Some private energy-service providers are already using local expertise to advance their business models; there are lessons to be learned from these efforts. In India, a private energy-service provider, DESI Power, has tapped into existing local expertise to build demand for its electricity services. DESI Power has built its model around the key notion of community development achieved through the promotion of both local energy resources and markets for development. DESI simultaneously invests in energy infrastructure and in local activities that stimulate the productive uses of energy, thus building sustained demand for its energy services. In the village of Baharbari, DESI Power partnered with a local cooperative called Baharbari Odhyogik Vikash Sahkari Samiti (BOVSS) to develop income-generating activities in the village. Through financing provided by DESI Power, BOVSS worked with the local community to develop commercial enterprises such as irrigation, milling, husking, and battery charging. Once these economic activities were established, DESI Power was able to provide household-level power to inhabitants of Baharbari who were now able to pay for these services (Schnitzer et al. 2014).

2.3. Leveraging Development-Oriented Funding for Electricity Access

Electricity planners can leverage development-oriented funding (from domestic, international, and other sources) to scale electricity access by means of cross-sectoral linkages between electricity initiatives and other development activities. By demonstrating the synergies between access to electricity services and the realization of other development needs, planners can present a strong case for extending development finance. Most development finance has focused on more traditional development sectors such as education, health, and agriculture (Rai et al. 2015). By coordinating efforts with development agencies in these areas, electricity planners and service providers can tap into a more diverse pool of funding sources for electricity access. They can engage development banks, donors, and others involved in sectors such as health, education, and agriculture to fund cross-sectoral programs that maximize both electricity access and other development outcomes.

We turn now to a discussion of good governance—the third element in our proposal for developing effective electricity access initiatives. This element is essential to ensure that electricity services, if provided, are actually within the reach of consumers who need them.

SECTION 3: BUILDING FOUNDATIONS FOR GOOD GOVERNANCE IN ELECTRICITY ACCESS

> A careful consideration of issues relating to affordability, quality, and reliability of service is key to ensuring that electricity services reach those who need them.

Good governance in electricity access involves issues such as who benefits from electrification efforts and the conditions necessary to ensure that the provision of electricity services is well aligned with public interests. The public interest is concerned with decisions relating to public expenditures, affordability, and the quality and reliability of electricity services (Wood et al. 2014). The Multi-tier Framework has built these governance considerations into its definition of access. Beyond the extension of physical access to electricity access across the different tiers, electricity planners and service providers will need to factor the issues of affordability, quality, and reliability of service into their planning efforts.

3.1 Promoting the Affordability of Electricity Services

If energy services are priced too high, they will be beyond the reach of many consumers. In sub-Saharan Africa and India, many households and communities in grid-connected areas cannot afford to connect to the grid and use the services it provides. Some grid-connected customers also suffer constant disconnections because they cannot pay their bills. Poor households that may be connected to the grid through public support programs may lack the financial ability to purchase electrical appliances and thus are unable to realize the full benefits of an electrical connection. As electricity markets evolve to include an off-grid component, different affordability concerns emerge.

Electricity planners and policymakers will have to address the entire range of affordability concerns for both grid and off-grid consumers in order to improve the chances that electrification efforts will succeed.

Affordability of Grid Connections

For consumers within reach of the central grid, a key affordability challenge is the cost of connecting to the grid. In sub-Saharan Africa, connection charges are perceived as the greatest impediment to grid service. Poor consumers usually cannot afford initial connection charges (which can be more than US$100 per household) even when they are able to afford the monthly charges once an electricity connection has been established (Tenenbaum et al. 2014). Some low-income consumers may be able to save enough to afford the initial connection charge but not the regular monthly payments at established tariff levels.

The typical government response to these affordability gaps has been to provide subsidies. Governments may offer subsidies to utilities to reduce the costs they incur when connecting new customers to the grid; this should, in principle, lower the connection charges that utilities levy on consumers. Governments may also offer subsidies directly to consumers to reduce tariff burdens. In some developing countries, governments have used social tariffs, also known as lifeline tariffs, to enable low-income households to afford electricity. In South Africa, the government instituted a "poverty tariff", called the Electricity Basic Support Services Tariff (EBSST), to supply free electricity to satisfy the basic needs of poor households. One study suggested that grid-connected low-income customers who were offered free electricity up to a 50 kWh/month threshold were relieved of their energy burdens by up to one-third (Winkler et al. 2011). In some cases, however, the lifeline tariff approach has failed to provide the necessary support for the poor. The government of Ghana established a subsidy scheme—the lifeline supply tariff—to support low-income residential consumers. The lifeline tariff was based on an estimate of the basic electricity requirement of rural and poor urban households. Their consumption was estimated at 50 kWh/month and was charged at a low flat rate (Edjekumhene, Amadu, and Brew-Hammond 2001). Later assessments found serious flaws in the subsidy scheme. In particular, the estimated 50 kWh/month proved insufficient because the target low-income populations lived mostly in communal houses with multiple families, which together consumed more than the lifeline consumption amount (ESMAP 2003).

India's flagship rural electrification program, the Deen Dayal Upadhyaya Gram Jyoti Yojana (formerly known as Rajiv Gandhi Gram Vidyutikaran Yojana), provides electricity connections free of charge to the poorest families (defined as falling below the poverty line). Studies looking into the impact of the program have found that the villages that benefited from the scheme have attained higher household electrification rates than those that did not (Jain et al. 2015). However, the implementation of the scheme has been beset by problems, including long lag periods between setting up grid infrastructure and establishing actual electricity supply for low-income consumers, intermittent supply (Jain et al. 2015), and, in some cases, exploitation by intermediaries who charge eligible families for connections that are supposed to be free (Greenpeace 2011).

These experiences point to the need for governments to ensure that subsidies are well designed and targeted to reach the intended beneficiaries efficiently. Governments should also monitor subsidy programs consistently to ensure that the intended benefits are actually realized (Tenenbaum et al. 2014).

Affordability of Off-Grid Connections

Affordability gaps exist in the off-grid context as well. A recent WRI study examining the socioeconomic impacts of off-grid energy systems found that microgrid customers in some parts of India spend 7–10 percent of their total monthly expenditure on basic electricity services such as lighting and mobile phone charging (Rao, Agarwal, and Wood 2016). As off-grid markets become an increasingly relevant component in addressing the electricity access challenge (IEA 2014), planners will need to address the issue of cost. Like conventional grid customers, consumers of electricity from minigrids can face challenges with connection charges and tariffs. If these costs are too high, they may not be able to access electricity produced by minigrids without support mechanisms.

Affordability concerns also exist in the solar home system (SHS) and lighting products markets; they usually relate to the inability of consumers to cover the up-front purchase costs. In response, some governments and development agencies have instituted programs to either lower the capital costs of systems or enable end users to spread their purchase of systems over time. For instance, in the Bangladesh IDCOL SHS program, IDCOL provides capital buy-down grants for SHS dealers; the capital cost reductions then trickle down to consumers through lower system costs (Rai et al. 2015). In India, the Ministry of New and Renewable Energy gives households that purchase SHSs from banks financed by the National Bank for Agriculture and Rural Development (NABARD) a capital subsidy of up to 40 percent. To benefit from the subsidy, however, consumers must purchase units that meet certain technical specifications and apply for a bank loan.[5]

End-user financing models have focused on creating avenues for consumers to pay for systems through flexible payment schemes. Energy-service providers have used hire-purchase models, fee-for-service models, and consumer loans to enable consumers to pay for off-grid systems. These models have had varying levels of success. In Kenya, energy enterprises that use hire-purchase models administer these loans primarily to employees in formal employment sectors, who receive regular paychecks. Technology suppliers establish formal agreements with the employers to supply equipment to employees. Monthly payments are deducted from the employees' salaries. Because of the focus on employees in the formal sector, consumers outside this sector (who are mostly "last mile" or "bottom-of-the-pyramid" consumers) are automatically excluded from these schemes (Rolffs, Byrne, and Ockwell 2014).

More innovative consumer finance approaches such as the pay-as-you-go (PAYG) model are overcoming the challenge of reaching bottom-of-the-pyramid consumers through technology-driven financing approaches. These private-sector models have seen widespread success in East Africa and have recently been applied by some enterprises in India as well. Under PAYG, technologies are adopted to facilitate real-time monitoring of remote payments for electricity services. PAYG businesses have tapped into the widespread reach of mobile phone technology to provide electricity services to rural low-income communities by facilitating remote and flexible payments that are well suited to the income-flow patterns of bottom-of-the-pyramid consumers (Alstone et al. 2015; Rolffs, Byrne, and Ockwell 2015). These consumers have traditionally been excluded from conventional financing approaches practiced by financial institutions based in urban areas.

In spite of the promise that the PAYG approach holds for reaching the poorest consumers, enterprises are facing obstacles that impede their scale-up and reduce the affordability of their systems. Ongoing WRI research in Tanzania and Kenya has revealed that expensive financing arrangements hold back the ability of some of these enterprises to grow and raise the costs that consumers have to pay for off-grid systems (Sanyal et al. 2016). Because local financial institutions view the PAYG business as a risky investment (owing primarily to insufficient knowledge about the sector and the creditworthiness of rural customers), they are unwilling to finance them. Enterprises have to rely on foreign debt to finance their businesses. Volatility in local currencies raises the costs of such debt financing and high costs are ultimately passed on to consumers (Sanyal et al. 2016). PAYG energy companies are also sometimes unable to afford the prohibitive cost of conducting market studies that would enable them to better understand potential consumers' income flows, energy expenditure patterns, and ability to pay for energy services—information that would allow more accurate targeting of their businesses (Rolffs, Byrne, and Ockwell 2014).

In both grid-connected and off-grid electricity markets, governments can facilitate efforts that make electricity services affordable for consumers. In Box 5, we highlight some key areas where government intervention can promote affordability of electricity services.

3.2 Quality and Reliability of Service

Quality and reliability of service are other governance indicators emphasized by the Multi-tier Framework as determinants of electricity access. Both grid-connected consumers and those served by completely off-grid technologies constantly face quality-of-service issues. The success of programs that attempt to link electricity with productive uses and other development sectors (as discussed in Section 2) will depend on the availability of sufficient and reliable supplies of electricity to support those activities. Studies in Bangladesh, Nepal, Uganda, and Nigeria show that frequent power outages and voltage fluctuations negatively impact the productivity of small

Box 5 | Government's Multi-faceted Role in Facilitating Affordability of Energy Services

- **Monitoring and evaluation of price support mechanisms for electricity access**
  Governments can develop effective monitoring and verification mechanisms that assess the costs and benefits of electricity subsidy programs to ensure that they are not regressive and that they respond effectively to the needs of the poor.

- **Building demand for electricity services**
  Subsidies and other price-support mechanisms may facilitate physical connections to the grid or distributed generation technologies, but, as discussed above, physical access does not automatically translate into the satisfaction of development needs. Governments can create opportunities that promote the productive uses of electricity, including for the provision of social services. By improving the purchasing power of consumers, price-support mechanisms can be phased out over time as consumers gain ability to pay for the full cost of electricity services.

- **Supporting emerging end-user finance models**
  Emerging business models such as PAYG, which have shown early signs of promise in reaching hitherto financially excluded remote rural areas with electricity services, can benefit from government support to reach appropriate levels of scale and replication. Governments can commit public financing to conducting and sharing in-depth market studies that provide energy-service providers with the information needed to make effective business decisions. The World Resources Institute is spearheading market studies of this nature in Tanzania and India; it has developed Energy Access Investment Maps to equip energy-service entrepreneurs in both countries with the market knowledge needed to make decisions about where to target their business. Governments can also commit public finance to build the capacity of local financial institutions to better understand the emerging PAYG sector and thereby reduce the institutions' perception of risk and their reluctance to finance the sector.

- **Incorporating technological development in telecommunications into electricity planning**
  Given the success of pay-as-you-go approaches in reaching bottom-of-the-pyramid consumers in some countries, governments could further promote the sector by ensuring that developments in the telecommunications and mobile money sectors are factored into the electricity planning process. In this way, effective support can be built for the pay-as-you-go sector in broader electricity access plans (Alstone et al. 2015).

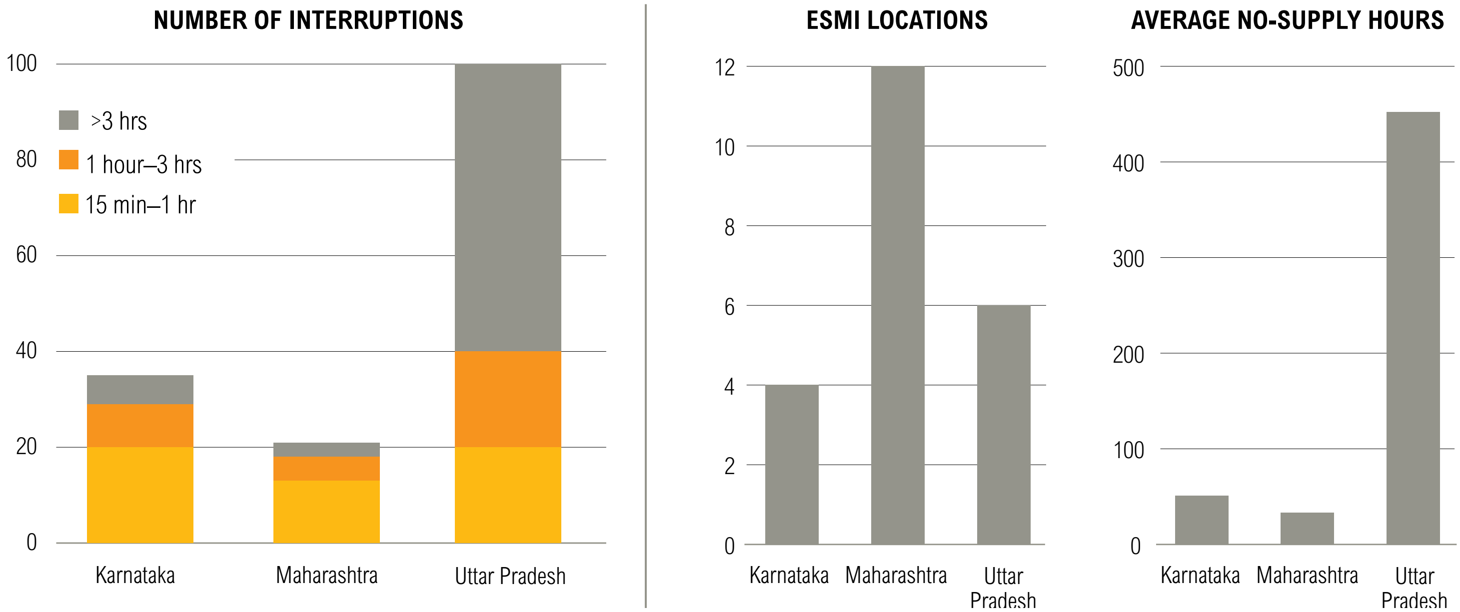
- **Establishing streamlined policies and regulations for distributed generation options**
  The structure of the policy and regulatory environment within which off-grid markets operate is a key determinant of the overall cost of equipment and electricity services provided. Cumbersome licensing and regulatory processes for minigrids can result in substantial transaction costs that affect the eventual costs of electricity services to consumers. Trade barriers such as high taxes and prohibitive import tariffs may also inhibit the growth of off-grid SHS and lighting-product markets. Government policies should be focused on removing these barriers through streamlined and transparent regulatory and policy processes. Clear policy and regulatory frameworks in the off-grid sector may also send positive signals to local financial institutions and other investors about the legitimacy of distributed generation options in promoting access to electricity, thus making them more willing to support the sector.

and medium-sized enterprises by halting production processes, damaging production equipment, and affecting the quality of the final products (Scott et al. 2014). In India, grid-connected consumers, especially in rural and semiurban areas, are compelled to invest heavily in alternative sources of electricity supply and other voltage-stabilizing equipment due to the poor reliability and quality of electricity supplied from the grid (Prayas Energy Group 2015). Low reliability also inhibits consumer decisions regarding investments that will be dependent on electricity, such as setting up a new business or purchasing expensive electrical appliances (Rao, Agarwal, and Wood 2016).

Quality and Reliability of Grid Electricity

Addressing reliability and quality-of-supply issues will require improvements in the technical characteristics of electricity supply systems as well as strong and effective structures for accountability in electricity service delivery. Electric utilities justify expenditures and tariff hikes on the basis of improving the quality of services supplied (Prayas Energy Group 2015). In the absence of effective monitoring mechanisms, the performance of utilities in achieving these service delivery improvements cannot be tracked or measured. Regulators and civil society groups can play a role in ensuring that utilities live up to their commitments. But to do this effectively, they will need to be equipped with the necessary information on service delivery metrics.

Figure 6 | **Quality of Supply in Rural Areas of India, January 2016**



Source: Prayas Energy Group 2016

The Prayas Energy Group in India is responding to this challenge by developing a database of electricity-supply quality metrics in various locations in India through its Electricity Supply Monitoring Initiative (ESMI). Plug-in devices called electricity supply monitors are installed in households, businesses, farms, and other locations to log data on voltage fluctuations and supply interruptions. The data captured are sent to a central server, analyzed, and made publicly available on a web interface. In January 2016, data were collected from a total of 138 locations, 110 urban and 28 rural. In each of these locations, Prayas Energy Group analyzed the data to ascertain the number of interruptions, number of hours of evening supply, and situations of no supply. Forty-three percent of the locations assessed had more than four hours of power outages per week, 17 percent had more than 30 power supply interruptions, and 12 percent experienced power outages lasting more than half an hour during evening supply hours. Quality- and reliability-of-supply issues were also found to be more common in rural locations than in urban ones (see Figure 6).

Quality and Reliability of Off-Grid Electricity

Reliability- and quality-of-supply considerations are also important in the distributed generation space. As off-grid options play increasingly important roles in bridging the electricity access gap, their ability to meet quality and reliability standards will be key to building consumer trust in these systems as viable electrification options. Regulators, civil society groups, and other nationally relevant agencies can play a monitoring and verification role to ensure that consumers get what they pay for.

The U.S. National Renewable Energy Laboratory is developing a Mini-grids Quality Assurance (QA) Framework that can be utilized by relevant national and subnational agencies to monitor the services provided by minigrid operators. Building on the multitier approach to electricity access, the framework does not mandate but defines a range of service levels applicable to communities without access. The QA framework factors

Box 6 | Regulating Quality of Minigrid Supply in India

In India, the Uttar Pradesh Electricity Regulatory Commission has developed a draft Renewable Energy Generation and Supply Regulation for existing and new minigrids in the state. The regulation is the first of its kind in India and requires minigrids in Uttar Pradesh to adhere to certain quality parameters. According to the regulation, the technical specifications of minigrids will have to conform to those applying to distribution companies (DISCOMS) for standalone systems. The draft regulation also covers safety guidelines, contractual agreements for selling power, and metering of connections. The draft was circulated in March 2016 and is still under review (UPERC 2016).

in the quality of the power produced (e.g., relating to voltage and frequency variations) as well as the reliability and availability of power (e.g., relating to the number of planned and unplanned outages and the number of hours of availability in a 24-hour cycle, respectively). The framework also includes an accountability element, which ensures that a specific level of service is actually received by the consumer. A second element of the accountability framework is *performance monitoring*, which ensures that minigrid operators provide the contracted service and comply with minimum safety and performance standards.

In the SHS and solar lighting markets, quality assurance is important to building consumer trust. Efforts such as the World Bank–led Lighting Global Initiative have developed quality assurance frameworks to protect consumers from poor-quality lighting products on the market. The Initiative provides baselines of product quality, durability, truth in advertising, quality of light output, and warranty provisions that safeguard the interests of consumers (Lighting Global 2016). To participate in the program, companies in the lighting-products markets must produce one or more products that satisfy these baseline metrics and pass a due-diligence screening test. Companies such as Mobisol, Azuri, Barefoot Power, d.light, and many more are certified associates of the Initiative (Lighting Global 2016).

At the national level, governments can provide support to ensure the quality of supply of lighting products. Whether through traditional regulatory agencies or other nontraditional regulatory agencies dedicated to the off-grid market, governments can direct public expenditure toward building safeguards that protect local consumers from poor-quality products. It is worth noting that poor-quality lighting products tend to flood markets because of their low prices. Consumers sometimes choose these products only because they are cheaper. In this case, it is important for energy-service providers and relevant government agencies to consider how innovative financing models can help address quality concerns in the off-grid market and encourage consumers to opt for better-quality products.

Traditional financing for SHSs has been provided mainly through solar loans. Financial institutions provide loans to consumers to obtain equipment from contracted suppliers. More often than not, the financial institutions have no technical knowledge of the technologies for which they are providing finance. They must rely on the technical expertise of the technology provider to fill these gaps. In Kenya, technology providers supplied consumers with substandard products and failed to provide after-sales customer support and maintenance services, leading to immense consumer dissatisfaction (Rolffs, Byrne, and Ockwell 2015). New financing mechanisms such as the pay-as-you-go approach are now serving as one-stop-shops for both financing and technology. Since service providers receive flexible payments for equipment and services over an extended period of time, there is an incentive for them to ensure that high-quality products are supplied and that customers receive after-sales support and maintenance. Mobisol, for example, focuses on providing high-quality equipment to consumers supported by after-sales customer care and maintenance. Customers pay for systems through flexible mobile payments over a period of time. Energy-service providers may find it difficult to provide after-sales service because of nonfinancial factors, such as physical distance from the customer. Service providers can train and use local expertise to provide the technical support needed in more distant locations. Local capacity building of this nature is a potential area for public support.

Engaging Multiple Stakeholders in Quality and Reliability of Supply

National electricity regulatory bodies have traditionally been responsible for monitoring quality- and reliability-of-supply issues. As distributed options such as minigrids and solar home systems come to play a larger role in electricity access efforts, capacity constraints within government regulatory agencies and other formal regulatory bodies may prevent these agencies from effectively monitoring the growing electricity supply landscape and its new cast of actors. Nontraditional actors such as civil society organizations (CSOs) and/or community-based organizations can play a role in regulating, monitoring, and evaluating the performance of off-grid projects. For instance, electricity service agreements can be signed between minigrid operators and village representatives. Service agreements could specify the nature of the service to be received, such as hours of electricity availability, and the maximum tariffs that will be charged. This has been successfully implemented in Cambodia, where a 15-year electricity service agreement was signed between Smau Khney village and a private operator. The private operator also provided an annual budget of US$200 to assist the village committee in carrying out its regulatory function.

With the private sector playing a greater role in the development of minigrids and the expansion of SHSs, the creation of partnerships between the private sector and civil society organizations could facilitate effective monitoring and evaluation as well. Establishing platforms for private-public engagement in the distributed generation sector could help to position CSOs and other community groups as honest brokers in off-grid projects. CSOs and community-based organizations can ensure that entrepreneurs provide quality products and services. They can also promote community acceptance of projects and provide the intelligence needed by private sector actors to make informed decisions about their potential markets and respond effectively to consumer needs.

CONCLUSIONS

The effective delivery of electricity services for the satisfaction of development needs requires that we look beyond conventional technology-centric approaches and adopt a more holistic perspective of electricity access. When a broader range of issues is taken into account, electricity access solutions can be designed that respond to development priorities and are accompanied by strategic efforts to address affordability and quality-of-supply issues.

We propose that efforts to address the challenges of scaling up electricity access adopt a demand-driven approach. It will be key to base electricity planning on a disaggregated understanding of demand that captures nuances in the energy-service needs of different consumer segments. Such an approach will, however, depend on the development of comprehensive databases of demand characteristics that can inform planning for the appropriate supply options to meet demand at the national and subnational levels.

A demand-driven response to the electricity access challenge also facilitates a clearer understanding of the actual development priorities that energy services can or should satisfy. This, in turn, creates opportunities for building the robust demand for energy services that will underpin the long-term sustainability of electricity access initiatives. Establishing linkages and exploiting synergies between electricity supply and other sectors of development demands well-coordinated interaction between stakeholders in these different sectors. Governments have a role to play in harmonizing the efforts of all development sectors in order to realize the full benefits of electricity access initiatives.

Together with the private sector and civil society, policymakers and planners can also devise effective solutions to address the affordability and quality-of-supply issues that too often impede access to electricity services and the satisfaction of salient development needs, even when the appropriate technologies are readily available.

RECOMMENDATIONS FOR POLICYMAKERS AND PLANNERS

The recommendations presented below identify some key interventions in each of the three areas identified by this paper as critical for implementing effective electricity access initiatives: namely, bottom-up demand forecasting, linking electricity access with development efforts, and building good governance. Planners and policymakers can focus on implementing actions in these areas, but they will need to work closely with multiple stakeholders. We identify relevant stakeholders with whom planners and policymakers can engage as they attempt to implement some of these interventions in their countries. The list of stakeholders is not intended to be comprehensive; it only serves as a guide that can be tailored to local circumstances.

	KEY INTERVENTION AREAS	WHO SHOULD BE ENGAGED?
Promoting the bottom-up estimation of electricity demand	■ Build databases of electricity end-use equipment and services in different consumer segments. ■ Liaise with private energy-service providers and NGOs to share market information and data on consumer demand. ■ Create a legitimate role for distributed generation options and energy efficiency in meeting electricity demand by including these options in national electricity policies and plans.	■ National and subnational planning agencies ■ Universities and research institutions ■ Private energy-service providers ■ NGOs
Establishing linkages between electricity access and other development sectors	■ Harmonize national policies across electricity and other development sectors. ■ Factor cross-sectoral linkages between electricity and other development sectors into electricity planning. ■ Build demand for electricity services by supporting the development of other development sectors, for example, by providing equipment to support productive activities in rural areas and establishing programs to support the development of small and medium-sized enterprises. ■ Compile information on the sector-specific benefits of electrification and make it available to local enterprises, development agencies, NGOs, and so on. ■ Continually monitor the impacts of electricity access on other sectors of development and vice versa.	■ National and subnational planning agencies ■ NGOs ■ Community groups ■ Development finance institutions ■ Donor agencies ■ Private energy-service providers
Building good governance principles (affordability, reliability, and quality-of-supply considerations) into electricity access initiatives	**Reliability and quality of supply** ■ Establish a transparent and participatory electricity planning process that incorporates input from relevant stakeholders on how public interests can be factored into electricity access planning. ■ Set up structures for transparency and accountability in electricity service delivery by both traditional utilities and private electricity-service providers. ■ Engage the services of nontraditional regulators such as civil society groups and community groups in monitoring and evaluating the performance of utilities and energy-service providers. **Affordability** ■ Frequently monitor price support mechanisms such as subsidies to ensure that they reach the target group and that the costs do not exceed the benefits. ■ Build demand for electricity services by supporting the development of other sectors such as industry, construction, and so on. ■ Provide support for research into and development of the role of emerging machine-to-machine technologies that support innovative financing models such as PAYG. ■ Integrate developments in the telecommunications sector into electricity planning. ■ Reduce prohibitive transaction costs in the off-grid sector by streamlining licensing and other regulatory processes and removing prohibitive taxes and import tariffs. ■ Support market studies in the off-grid sector. ■ Support technical training in rural communities that focuses on equipping local people with skills to operate and maintain off-grid systems. ■ Build the capacity of local financial institutions to better understand emerging end-user finance models such as the PAYG model.	■ National and subnational planning agencies ■ Regulatory agencies ■ Civil society groups ■ Private sector actors ■ Development finance institutions ■ Donors ■ Universities and research institutions ■ Telecommunications sector ■ Local financial institutions, such as local commercial banks

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ENDNOTES

1. In the context of this paper "electricity demand" refers to both unmet and latent demand for electricity services and the ability of consumers to pay for electricity services.

2. "Energy elasticity" refers to the energy intensity of GDP. It is the percentage change in energy consumption needed to produce a 1 percent growth in GDP.

3. Ghana's appliance standards and labeling program was the first to be developed in sub-Saharan Africa. Efficiency standards and labels have been established for consumer products such as air conditioners, compact fluorescent lamps (alongside a program to completely phase out incandescent light bulbs), and residential refrigerators.

4. Communication with SELCO India, June 6, 2016.

5. Customers have to make a down payment and maintain a balance in the bank. See NABARD Circular No. 102/DoR-GSS-34/2014 dated June 18, 2014 (https://www.nabard.org/uploads/Solar%20-%20Modified%20Scheme.PDF) (last accessed May 9, 2016).

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World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.