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Planning for Electricity Access

THE BOTTOM LINE

That "electricity for all" campaigns around the globe often fall short of their targets is partly a failure of planning. In the area of generation and transmission, technical changes could improve the handling of key constraints, such as fuel availability, funding, and the rate of building. Planning for distribution networks could be improved by gathering data on end-use demand and deploying geospatial tools. Most important of all, the entire planning process—from generation to distribution—must be better coordinated if access plans are to be successful.

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Why is this issue important?

Better planning can improve the success rate of programs to expand access to electricity

With about 1.2 billion people around the world still lacking electricity, access to reliable power remains a global development challenge. However, "Electricity for All" programs in many countries of South Asia, Sub-Saharan Africa, and Latin America are behind schedule. India, for example, had originally set the goal of achieving 100 percent electrification by 2012, but a quarter of its population, or more than 300 million people, are still without access to any form of modern energy services.[1] The new government has recently announced a revised target of 2022. In Sub-Saharan Africa, nearly 600 million people—two-thirds of the region's total population—and 10 million small and medium-sized enterprises have no access to electricity. Per capita electricity consumption in Sub-Saharan Africa (excluding South Africa) averages only about 124 kWh a year, barely 1 percent of typical consumption in high-income countries and hardly enough to power one light bulb per person for six hours a day. The region (again excluding South Africa) consumes as much electricity each year as the state of New York (IEA 2010).

Lack of access to modern energy services is a major impediment to efforts to reduce extreme poverty. It impedes education—for example, because children are unable to study at night—and saps productivity and competitiveness because businesses, markets, and clinics must restrict their operating hours.

Solving the problem is not a simple matter. The level of effort needed to enhance access is immense. Notwithstanding significant progress made between 1990 and 2010, the pace of electrification must double in order to reach 100 percent electrification by 2030—a goal set by the United Nations General Assembly in 2012 (World Bank 2013). And, ironically, achieving meaningful improvement in energy access will require raising the very low per capita consumption targets that are often part of Electricity for All programs (Bazilian and Pielke 2013).

Finally, more extensive and realistic planning that takes into account physical, financial, and institutional constraints—will be needed to improve the effectiveness of electricity access programs by devising a technology mix and schedule that are more likely to be achievable. There is also ample room for better planning to select the best mix of grid and off-grid distribution.

This note highlights the importance of coordinating planning activities across the electricity supply chain from generation to demand, including new connections, to better plan for electricity access.

What is the key challenge?

Electricity planning in most developing nations suffers from common shortcomings

Planning for generation and transmission typically includes preparation of a master plan every three to five years, complemented in many cases by annual or biannual national plans from the energy ministry. Most such plans—which are too often based on the aspirations of governments and on political considerations—have done no more than provide a broad guide, typically a schedule for the installation of additional capacity that quickly proves overoptimistic and falls behind for lack of investment. Planning in Bangladesh and India, for instance, has not reflected the serious primary energy

[1] The failure to meet targets in India and many other countries can be tracked to generation and fuel supply constraints that were overlooked or ignored when targets were set.

crunch that has cut back gas and coal generation. Assumptions about the rate at which generation and transmission assets will be built have almost never been met in either country. As generation lags behind, transmission and distribution assets go underused and access to electricity is not expanded.

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The **off-grid programs** (such as solar home systems) that have emerged to fill the vacuum are relatively expensive, have their own share of problems of reliability and quality, and ultimately do not expand access beyond basic household needs. Although such approaches may be a necessary part of an overall access plan, they are too often introduced with the unexamined assumption that the grid will not reach parts of the country for many years and that the per capita power consumption of low-income households will remain at a subsistence level. There are some exceptions. Bangladesh's solar-home-system program has filled an important niche in face of severely constrained electricity supply. Off-grid programs implemented by the private sector on market principles are more sustainable than similar programs operated by grid utilities with capital and operating subsidies. But when they are implemented outside the purview of grid utilities, the latter cannot integrate them into their planning.

Planning of distribution systems is limited or nonexistent in most countries, even among the top-performing state utilities. Insufficient information on existing and new customers (including off-grid demand) makes it impossible to estimate future demand. Decisions about grid extension and off-grid electrification are driven by policy targets, with only limited planning and analysis to guide the operation of the system (World Bank 2014), the selection of transmission and distribution components, and the optimization of grid extension with off-grid solutions. An assumption typically implicit in planning of distribution assets is that the available supply of electricity will be adequate, which is not necessarily true. When supply proves inadequate, the utility usually ends up buying power at an exorbitant rate, building small and expensive diesel-powered generation plants or falling back on solar home systems and other off-grid solutions. Meanwhile, firms expand their reliance on back-up generation.

In short, even when rural electrification programs succeed in erecting poles and wires, supply in many cases has been too unreliable to provide meaningful service, especially for economic activities.

What solutions are available?

More ground-level data and better coordination of planning processes will improve outcomes

Traditional planning tools and processes in electricity generation and high-voltage transmission are generally adequate but could be improved to better capture constraints that either were historically absent (for example, the intermittency of certain renewables) or were not binding enough to invalidate planning outcomes (for example, the supply of gas and oil). Bangladesh presents an example where the planning studies undertaken in 2005 largely missed the impending gas shortage, anticipating more than 21 GW of new gas-based capacity in the base case (NEXANT 2005/06). The subsequent master plan developed in 2010 corrected for this problem to some extent (JICA 2011). The resulting plan was much more diversified, with domestic and imported coal accounting for more than half of the planned capacity.

Much better *coordination* of generation and transmission is needed, especially as power networks in the developing world become more interconnected (within regions of a single country, between countries, or among several countries in a given region).[2] Similar enhancements are needed to anticipate and account for cross-border power trading, where this already exists or may be advantageous. India's Central Electricity Authority has for decades relied on a sequential planning process that tailors transmission to generation without placing sufficient emphasis on grid-reinforcement projects that could reduce the need for peaking generation in some parts of the network. In its latest national electricity plan, the authority partly remedied the problem by developing subregional grids to reduce system costs (CEA 2012). Recent planning efforts in India demonstrate a more explicit recognition of the additional investment needed for grid reinforcement. However, recognition remains limited of cross-border power trading opportunities that could help India address the problem of access to electricity.

Finally, the forecasting of demand must be drastically improved. Historically, demand for electricity has been assumed to correlate strongly with economic growth. While the gross domestic product

[2] Such coordination between generation and transmission is not easy to achieve because of increasing institutional separation and because financing may come from different sources.

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provides a helpful guide to aggregate demand, "hot spots" often are not captured. Accurate demand estimates depend on realistic estimates of *disaggregated* demand, including suppressed demand. Preparing such forecasts may involve a significantly higher level of effort. But as the work by Parshall and others (2009) and ongoing work at the Columbia University Sustainable Engineering Lab (http://sel.columbia.edu/projects/) make clear, this approach has the potential, by integrating network planning with demographic data, to produce realistic supply plans and to blur, to the extent possible, the boundaries between distribution and upstream generation and transmission.

New bottom-up approaches for demand estimates, such as planning tools based on geospatial data, should be incorporated wherever the requisite information is available or can be developed with relatively little effort. This is particularly important in planning distribution networks. With bottom-up approaches, planners can gather substantially more information on customers (for example, the location and income level of households) and then use structured analysis to gain a detailed view of demand and, on the basis of that analysis, decide on the best way to extend the grid or to rely on off-grid solutions, as the case may be.[3] The costs of connecting new customers to the grid must be properly accounted for in determining the best course of action. Where those costs are underestimated, superior off-grid solutions may be undermined.

The importance of strategic and operational planning has been recognized in the last decade. Hawkins (2007, 2009) presented early ideas for improving distribution-network planning using General Electric's SmallWorld software. Introduced in 2009/10, SmallWorld (GE 2010) uses spatial information to help planners understand where new networks should be targeted, where additional investment is required to meet forecasted demand for capacity, and where a business justification for investments in network upgrades may be needed. Network companies and distribution utilities in developed countries have begun to rely on these tools to support the business cases they present to regulators.

The concept of planning based on geographic information systems (GIS) has also been applied in developing nations such as Kenya to gather and analyze information on where and how people live so as to improve their access to services and markets (Parshall and others 2009). Min and others (2013) report findings of a World Bank–funded research effort to use night-imagery data gathered by the U.S. Air Force's Defense Meteorological Satellite Program to monitor power consumption in more than a thousand villages in Senegal and Mali. This is a relatively new but promising area in which significant effort is needed to develop and integrate the necessary data across jurisdictions to improve system-level planning and merge traditional engineering-focused methods of distribution planning with geospatial planning. For more examples of research on geospatial applications to power-system planning, see box 1.

Ideally, geospatial planning tools should be developed not at the utility level but at the national level. The scale of such an operation, including the need for coordination across relevant sectors (water, electricity, roads, telecommunications) poses a significant challenge. Real-life implementation of geospatial planning has tended to focus on individual sectors and to be confined to relatively small areas within a country. In an ongoing World Bank project in Nigeria, a geo-spatial least-cost model is being developed for a small region within the country by digitizing the existing grid network and overlaying it with technical, demographic, and economic data. The technical data elements needed for efficient distribution network planning analysis are digital mapping of the grid network and information on demand, supply (load), and resource availability. Necessary demographic data include population density and growth patterns (urban and rural sprawl), and social institutions (health centers, schools, government offices). Also needed are data on customers' ability and willingness to pay for electricity based on poverty trends, household incomes and expenditures, and commercial and industrial activity. This extensive data set is created using simple and modern mapping techniques based on a GIS-embedded global positioning system.

The critical areas in which planning must improve if it is to address access in a rigorous way are summarized in figure 1.

Before sound distribution planning can be initiated, generation and transmission planners must have access to bottom-up forecasts that capture realistic demand and supply inputs. Planners need to realize that, to be meaningful and sustainable, access to electricity should be conceived not as a steady state of subsistence consumption but rather in terms of rising demand over time (World Bank 2013;

[3] Again, the efforts and costs involved in developing GIS datasets and tools can be quite extensive, especially in a developing country. Nevertheless, geospatial planning has been successfully implemented in several developing nations, as discussed further on.

Box 1. Major research efforts in geospatial planning

Despite promising beginnings, geospatial planning is still in the research and development stage. These three research groups are among those most active in the area:

- The Earth Institute at Columbia University has undertaken significant geospatial planning exercises over the past 10 years in several countries of Africa, Asia, and Oceania—including India, Indonesia, Papua New Guinea, and Kenya (Parshall and others 2009); Liberia (Modi and others 2009); and Senegal. Under the leadership of Professor Vijay Modi, the Earth Institute is also implementing an ongoing Bank-supported program in Nigeria that is piloting geospatial least-cost planning in selected distribution zones while ensuring that the sector master plan is developed and updated in coordination with the distribution plan.
- Professor Ignacio Perez-Arriaga of the Massachusetts Institute of Technology and Universidad Pontifícia de Comillas is currently undertaking research on a comprehensive modeling framework to combine GIS data on households, a "reference electricity model" for the design of networks, and an energy planning model to analyze the impact of access policies across the economy (Perez-Arriaga 2014).
- KTH Division of Energy Systems analysis (KTH/dESA), under the leadership of Professor Mark Howells, has performed analyses based on geospatial planning for the 2015 World Energy Outlook of the International Energy Agency. Their recent work in Nigeria, for example, includes an extensive analysis of high- and medium-voltage network expansion compared with off-grid solutions (Howells 2014).

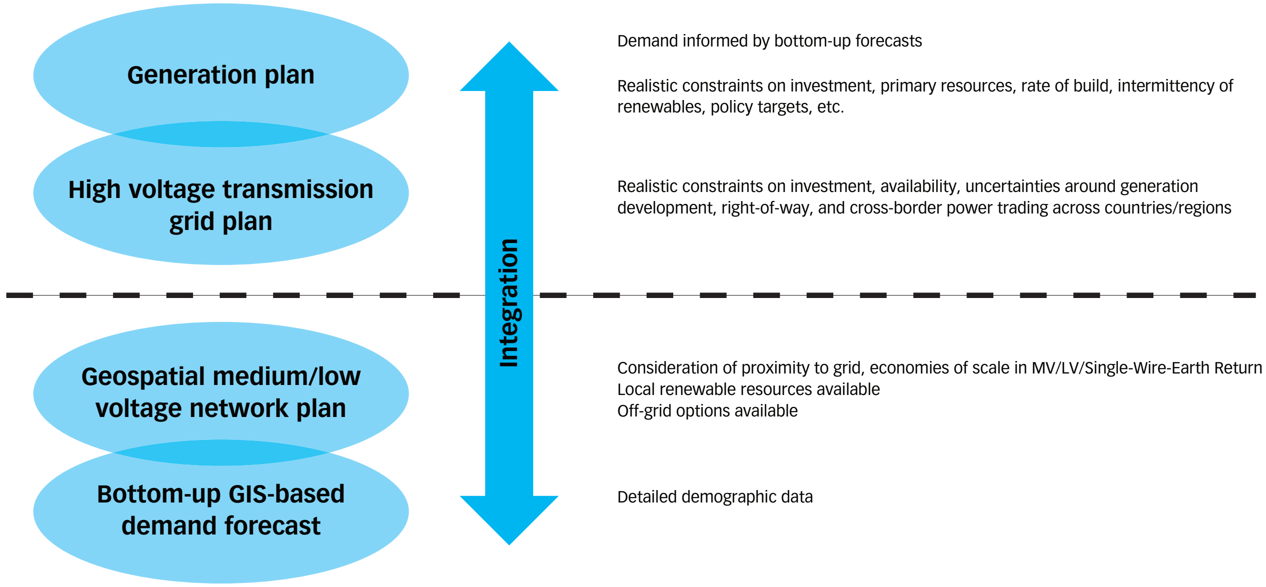
"By combining GIS-based data with conventional distribution-network planning tools (such as load-flow software), designs for distribution networks can be made to reflect real conditions on the ground and thus provide guidance on the best way to enhance access."

Bazilian and Pielke 2013). They should also realize that generation and transmission plans have often failed to recognize constraints on the growth of generating capacity.

Planning of the medium- and low-voltage (MV/LV) distribution network, in turn, should be based on the forecast availability of electricity at the substation level for the forecast years. The level of availability will drive decisions to extend the grid or to rely on off-grid solutions. An important element in such planning is the extent of locally available renewable resources that may either be connected to the grid or become part of off-grid solutions (mini- and microgrids). Excellent planning tools, such as HOMER (http://www.homerenergy.com/), are available to help planners make the right decisions. By combining GIS-based data with conventional distribution-network planning tools (such as load-flow software), designs for distribution networks can be made to reflect real conditions on the ground and thus provide guidance on the best way to enhance access (Hawkins 2007, 2009).

Although not explicitly the focus of this note, the commercial viability of distribution companies, especially in countries where utilities have been privatized, is an important aspect of effective planning. Least-cost approaches, properly used, can help maintain the financial health of the sector, while incorporating affordability and other sociopolitical objectives through a system of graduated tariffs and subsidies. Once technical aspects are identified and planned, private distribution companies can be incentivized to make investments in infrastructure such as substations, transformers, MV/LV line extensions, and so on, through a system of capital subsidies using a combination of direct subsidies (capital buydowns), indirect subsidies (tax credits, amortization allowances, trade and import incentives), and output-based allocations (connection subsidies). Targeted support (such as for pro-poor and gender-based policies) can be offered to distribution companies to recover the ongoing cost of supply and maintenance of assets through a combination of direct tariff subsidies (for households that consume small amounts of power) or cross-subsidization by consumers of larger amounts of power.

Figure 1. Planning framework for electricity access



Source: World Bank.

"Future R&D efforts should be directed not only at enhancing specialized tools, but at improving how those tools can be effectively coordinated to support the development and execution of a long-term access strategy."

What have we learned?

Understanding demand and integrated planning are the royal road to expanding access to electricity

The persistent failure of "electricity for all" campaigns around the globe to meet their targets demonstrates that increasing access to electricity is a challenge not fully understood. Institutional weaknesses, political interference, and the need for financing have all been identified as components of the challenge. But sound technical planning deserves no less attention. Even in the mature area of planning for generation and transmission, where the key ingredients already exist for better planning, small changes could improve the prospects of success of efforts to widen access to electricity. Defter handling of key constraints, such as fuel availability, funding, and the rate of building, would allow generation and transmission master plans to better guide access strategies. There is an equally pressing need to improve the planning of distribution networks by deploying geospatial tools to gather and analyze data on end-use demand.

Most essential of all, the generation, transmission, and distribution components need to be well coordinated if access plans are to be meaningful. No universally agreed methodology or planning tool yet exists to facilitate the necessary coordination. Future R&D efforts, as well as project planning by the World Bank and other donors, should be directed not only at enhancing specialized planning tools, but at improving how those tools can be effectively coordinated to support the development and execution of a long-term access strategy. A more holistic approach to project planning would seem to be indicated, both nationally and from the World Bank's perspective. Small, individual Bank projects probably will not be as effective in widening access to electricity as a continuous project that supports GIS system development over a period of, say, 10 years.

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Available tools, properly used, can also inform policy interventions by governments and support the mobilization of resources (public, private, and donor-funded) behind access initiatives. There are many potential impediments to successful implementation of such initiatives, including political and social barriers. But a case backed by scientific data, rigorously gathered, will always have a better chance of overcoming these barriers.

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