6 Key drivers of improved access—off-grid service

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Message from the editors

For the foreseeable future the prospects of better energy services for many of the poor will depend not on the wholesale expansion of electricity and gas networks, but on finding better, cheaper off-grid energy sources. In rural areas and city slums ways must be found to bring down the costs of cleaner, more reliable fuels and the costs of doing business in supplying and serving poor communities. Poor communities and households need help in making informed choices between energy services and may have to take collective action to secure them. Financing hurdles for consumers on the margins of the cash economy must also be overcome. Both technological and commercial innovations are needed—to bring down the costs of producing energy and of financing and managing services. While there are many promising developments, the costs of implementing innovative off-grid projects remain high, and the challenges of scaling up are daunting. In this context, two government roles are likely to be critical. First, reforms are needed not only in energy networks but in the broader energy markets on which many of the poor rely. Second, the use of subsidies must be improved in ways that encourage innovation.

What would a well-developed market for off-grid energy services look like? It would offer an array of energy solutions to meet (mostly rural) consumers' needs—standalone photovoltaic systems, battery charging stations, minigrids powered by sun or wind, and isolated systems based on diesel, hydropower, and biomass. It would supply natural gas, propane, and kerosene for heat and refrigeration, and diesel and gasoline for productive uses. Households and entrepreneurs would have access to accurate, easily grasped information on products. Local shops would sell replacement parts and services. Vendors and developers would have access to accurate, current data on customers and their location, organizations, grids, solar radiation, rivers, topography, and wind speed and direction. They would have simple, robust analytical tools for selecting technologies. Prices would be set freely, and vendors would be able to use financing mechanisms to spread capital costs over much of the useful life of their investments. Energy goods and services would become commodities bought and sold at the local store, and governments and donors would have flexible means for supporting consumers' choices through subsidies and other assistance.

Nowhere have such markets yet been created—with organizations operating on a level playing field and collectively driving the process of electrification. Decisions on off-grid provision are still largely dominated by governments, donors, and nongovernmental organizations (NGOs). But there has been much experimentation with methods of delivering off-grid service, particularly in the electricity sector (the primary focus of this chapter). These experiments cast light on the key factors that could drive service improvements in rural areas in the future: technological advances that reduce costs and increase ease of use and maintenance of small-scale electricity systems by households and communities; organizational innovations that help communities choose, implement, and maintain improved systems; and innovations in financing—with or without the aid of subsidies—that help poor households over the hurdle of high capital costs for new services. This chapter describes some of these innovations, and the role they could play in extending access to electricity beyond the reach of grids.

The off-grid market in the post-privatization era

Electricity sector restructuring tends to center on existing grid distribution systems, their electricity supply, and the

rights and obligations of their customers. Any effects on actual or potential off-grid customers—who would use different technologies, supplied by new market players—tend to be accidental. In reality, opportunities for improving services through market reforms are not restricted to the grid-based part of the energy sector. Off-grid, too, there is potential for reforms to spur innovation in the design, delivery, and financing of energy services.

The central planning–type approach by governments and donors to technology selection does not work.

Off-grid markets pose serious challenges. Distance from existing lines, dispersion of potential customers, and low energy consumption make access to electricity service through grid extensions more difficult, regardless of who owns distribution utilities. Private utilities will not build unprofitable lines unless explicit subsidies (or embedded cross-subsidies) more than compensate for any financial loss over the life of the project.

That being the case, reform programs should include improved access to electricity service for potential customers, regardless of their location with respect to the grid, in a way that is consistent with a more competitive market structure, private participation, and independent regulation. The challenge is to understand the limits of grid expansion—particularly when initial investment may be focused on rehabilitation rather than network build-out—and to ensure an incentive structure and demand drivers that will allow alternative suppliers to compete to serve the unconnected.

This goal raises some difficult questions for the policy designers who will have to structure markets that lead to the right solutions, perhaps including subsidies:

- What technology is most appropriate for bringing electricity service to a given population? What are the costs and benefits of the options, and how should the choice among them be made?
- If the electricity service differs in quantity and quality from grid electricity, how does this affect consumer satisfaction? How does it affect the demand for electricity and for other energy sources?
- A distribution utility, with professional management, may not be involved in delivering off-grid electricity service. Who is going to introduce, operate, maintain, and repay the costs of the institutions and technologies for service provision?
- Off-grid electricity sources tend to have much higher capital costs than grid service. How are these to be financed, given the limits of short-term credit and the low incomes of most who live off-grid? Many off-grid electricity sources have a long useful life, but their installation must be amortized over much shorter terms.

Technology drivers

By contrast with grid-based supply, the technology options off-grid are highly varied—in generation technique, in cost characteristics, and in the kind and quality of electricity service delivered. As noted, governments and donors still make most decisions about which off-grid technologies to use. Their decisions are generally based on four main criteria:

- *Kilowatt-hour per kilometer of line.* Consumption density is used as a criterion for deciding whether to build a line. The decision threshold must be adjusted to reflect prevailing net revenues and line construction costs.
- *Distance from the line.* Where density, consumption, and construction costs are similar, planners use distance from the line as a rule of thumb.
- *Least cost.* Some algorithms estimate the cost of providing a kilowatt-hour to consumers using different technologies under different conditions. Tables have been prepared comparing line extensions with diesel systems for varying distances from the grid and different numbers of customers, for example. While useful, these tables need to be continually updated. Moreover, they tend to ignore differences in quality between off-grid sources and fail to take full account of the potential benefits from each source.
- *Highest net economic benefit.* Estimates of net economic benefit take into account quality differences between energy sources and compare their potential benefits. But they must be prepared for every project by qualified personnel and are expensive.

In practice, the most basic rule of thumb in rural electrification is to try to make the off-grid market as small as possible. If governments, NGOs, and donors can put a community on the grid, they try to do so. The cost per customer ranges from US$250 upward. At US$10,000 per kilometer of line, a village of fifty users 3 kilometers from the grid will begin hitting the “photovoltaic ceiling,” about US$650 per customer (including installation and some training). At 5 kilometers, a village that size should seriously consider the photovoltaic option. If the wind blows hard—say 8 meters a second—it might consider windpower, but the right conditions are rare.

Small hydropower plants pose unique difficulties. Their energy production is determined by turbine size (and water flow, of course). Say 50 kilowatts are installed to serve a village of 200 people. First the line must be built from the plant to the village. Then the minigrid must be installed. But the real problem is that demand peaks at 7:00 p.m., when almost all 50 kilowatts are used, but at 3:00 a.m. the demand falls to 10 kilowatts or less and stays that way until the noon peak. As a result the plant capacity factor is extremely low, maybe 30 percent, but all 50 kilowatts must be paid for, at about US$1,500 per kilowatt plus the grid and the line—this could be as high as US$600 per user or as low as US$250. Then the community grows and needs an expansion, or demand increases and another unit has to be added. Small hydro plants are a rigid option. Still, when conditions are right, they are a possibility.

Photovoltaic costs seem to have leveled off, casting doubt on the long-term potential of this market premised on continual cost reductions. Still, many experiments are under way (see chapter 11). One is to use smaller panels, say 35 rather than 55 watts, to reduce the cost. Other ways to cut costs are to make batteries smaller and to omit controllers, unnecessary for occasional use though risky for the longevity of the battery. Another option is to pair off customers, for example, having some charge their batteries at their neighbor's on alternate days. But the essential condition is very low consumption, no more than a couple of lights and a radio. These are more organizational arrangements than technical drivers, but a smaller, less expensive panel, a fuse-type control, and a smaller battery could certainly lower the photovoltaic ceiling in some cases, perhaps to US$450 for a 55-watt system. (There is some regional variation in prices and in average system sizes.)

By contrast, there is no apparent way to make wind or hydro systems any cheaper, though connecting them to the grid opens new possibilities.

The central planning–type approach by governments and donors to technology selection does not work in most places. Customers and service suppliers are not consulted in any meaningful way, there is no strong sense of ownership of projects, and users lack an understanding of the true costs of supply. As indicated below, the government should allow customers and service companies to make the technology decisions, while it assumes a facilitating role. They may continue to use the same selection methodologies or they may devise new ones. The key change required is that providers and consumers decide.

Technology meets demand—learning to live with what you have

Technology selection should mesh with willingness to pay and service requirements. Off-grid electricity—except that from twenty-four-hour diesel systems and overdimensioned hydroelectric or biomass plants—differs from grid electricity in that consumption must be actively adjusted to the supply:

- Some systems provide service for only a few hours a day and thus would not allow refrigeration and other continuous or off-peak electricity uses. Households and businesses would use kerosene or propane for cooking, and fossil fuels to power productive equipment.
- A mini-hydro plant either supplies insufficient power to meet peak demand or has excess capacity off peak. So consumers must ration their electricity or develop uses for off-peak supply to ease the financial burden.
- Wind- or solar-powered minigrids require an expensive bank of batteries, which puts a financial cap on the system's capacity. Electricity service is often limited to fluorescent lights, radio, and television, and mechanisms are needed to prevent excessive consumption by any users.
- Photovoltaic systems give users the service provided by one or two batteries of 6 or 12 volts, 110–115 amperes. That limits uses to basic lighting and some electronic equipment.

Electricity differs in quality from other types of energy. Small amounts are enough to power a radio, a television, sound equipment, and, in some cases, even a cellular phone and a laptop computer. Because other energy sources cannot substitute for electricity in these uses, its economic benefit is higher than in cooking, heating, and pumping water, for example (Villagran and Orozco 1988).

Consumers with grid electricity have "the benefit of opportunity," the convenience of instant, unlimited availability. But consumers with access to very limited amounts of energy from such off-grid sources as photovoltaic panels or wind-powered battery charging stations are forced to rationalize their use of electricity, using it where it tends to generate higher relative benefits. The amounts of electricity supplied by these sources are so small, however, that the tradeoffs between competing uses are often painful.

A variety of energy sources can be used to meet off-grid communities' energy needs. Lighting and some electronics might be powered by photovoltaic systems, while refrigeration and cooking depend on propane or kerosene. Markets for alternative energy sources such as propane and kerosene can be stimulated in parallel with limited-supply electricity sources. In many countries the development of such markets is blocked by government interventions to subsidize prices and control quantities (box 1).

Organizational drivers meet demand—choice in implementation, operation, and maintenance

Whether a rural community or household gets an energy service well targeted to its needs and preferences depends not only on the availability of suitable technology, but also on the presence of institutional arrangements that provide

Box 1 **Developing the market for liquefied petroleum gas**

The global supply of liquefied petroleum gas (LPG) is about 120 million tons a year, or 3.3 million barrels a day. (The global oil supply exceeds 75 million barrels a day.) The LPG supply chain—from the relatively concentrated production sector to the highly fragmented distribution sector—grosses more than US$50 billion a year.

LPG is a blend of hydrocarbons heavier than natural gas but lighter than refined oil products such as gasoline and kerosene. Typically, it is a blend of propane and butane that is gaseous at normal pressure but liquid when modest pressure is applied. About 80 percent of the world's LPG is sold in the familiar metal cylinders—in most emerging markets it is referred to simply as "bottled gas."

LPG is a by-product of two very different oil and gas production processes. Oil companies and state-owned enterprises account for about half the sales of LPG to final customers, and independent marketers—often very small businesses—for the other half. This fragmentation has resulted in a lack of standard business practices. So customers cannot always be sure that the LPG bottle they buy has been properly filled, contains LPG with the right energy content, and is not defective.

In developing countries, where LPG is in most demand as a cooking fuel, the market faces two main challenges. First, both the sale and consumption of LPG requires special infrastructure. Consumers must invest about US$20 to buy the cylinder, a significant outlay for many households. Governments need to assess whether this up-front cost shuts some households out of the market, and how they could ease this initial transaction.

Second, because LPG is perceived as largely a household fuel, most governments subsidize its price and control quantities. The resulting market distortion tends to reduce the availability of LPG. When governments try to maintain different prices for different classes of consumers, they magnify this distortion. And because world LPG prices track world oil prices, government attempts to regulate LPG prices often impose large fiscal burdens.

To realize the full promise of LPG, governments should:

- Deregulate oil product and LPG prices, to relieve themselves of potentially huge fiscal burdens and allow a real market to develop.
- Pay more attention to standards and business practices, so that consumers perceive the LPG market as fair, safe, and reliable.
- Alter the business environment in ways that allow LPG supply, marketing, and services to flourish. A strong market would inspire a shift in the business strategy of the big LPG producers—from regarding LPG as a nuisance to seeking to market the product as a value added service.

Source: Manley 2000.

incentives for technological innovation and for tailoring technologies to local circumstances. In theory, an electric utility, like any other company, would use whatever technologies are available to serve as many customers in its territory as possible. In practice, distribution utilities are largely run by line builders and consider solutions other than grid extension expensive and unreliable.

Competition for the market to connect new customers might encourage distribution utilities to become more innovative in the service delivery options they offer. That requires a market structure that allows open entry—a free-for-all to hook up new customers. Regulation would focus on simple rules (open licensing procedures, standards) and on minimizing transactions costs (through provision of standardized documents, tariff and business models, and access to information).

Such a market would probably give rise to new organizations, competing for their share of the off-grid electricity service market. In this complex, largely undeveloped market new organizations would be shaped by the effective demands of consumers and the actions of governments and donors. Where the market is better developed, with more—and wealthier and more educated—customers, stronger, more sustainable service providers would probably flourish. In the early stages of market development in poorer, illiterate regions, there is a risk that unscrupulous suppliers might make a killing by selling expensive systems that work for only a short time. This early phase would call for increased consumer education.

A range of organizations now offer off-grid electricity service.

Photovoltaic service companies

Some private companies and NGOs supply, install, and maintain photovoltaic systems in exchange for a periodic payment. Most are heavily subsidized by governments and donors. It is expensive to inspect and maintain small, dispersed systems and collect payments from their users. But

the arrangements used allow the companies to amortize the panels over a period closer in length to their expected useful life, which is supposed to be thirty to forty years, rather than five or ten. In Guadeloupe and Martinique, for example, a French energy company, TOTAL Energy, supplies photovoltaic systems with one, two, or three panels, depending on demand, and charges users per kilowatt-hour. Customers use a prepaid card to purchase the number of kilowatt-hours they want, buying another card when they have used them up. In a sense, they are purchasing metered electricity. (In other photovoltaic mini-grids used elsewhere, fuses are used to limit energy use by any one customer.) TOTAL Energy grids remain heavily subsidized by the French government. It is hard to see how the company, charging US$5 a month, could cover its interest payments, much less any operating and maintenance costs, so it is not yet clear whether this concept is ready to fly.

Most off-grid systems have a long life, their initial cost is high, but finance is only short term.

Village committees

A model being used in many countries for stand-alone photovoltaic, mini-hydro, and even diesel systems—with mixed success—starts out with a village committee lobbying for access to electricity service for its community. Once a system is in place the committee operates and maintains it, collects payments or replacement charges, amortizes credits, and procures replacement parts. Committees are rarely formal legal entities, have idiosyncratic decisionmaking methods, and own no assets. Sometimes they lack the authority to enforce their decisions and are subject to pressure from influential citizens, especially relating to payments. Their members—ordinary citizens—may be poor administrators. And some users of the service may be unwilling or unable to participate. But committees are easy and inexpensive to organize and run, they tend to be legitimate representatives of their communities, and they can work even if not all users participate.

Local vendor representatives

Some photovoltaic vendors use local agents to perform basic maintenance and encourage adequate battery replacement. These agents also troubleshoot and give advice. Although their fees add to the cost of the systems, they provide a local presence and a better understanding of local needs and problems. With subsidies and assistance from the German government, photovoltaic system vendors in Senegal operate through local electricians, who sell, install, and maintain systems. A sizable, private, largely unregulated photovoltaic industry has developed in Kenya (see chapter 11).

Rural electric cooperatives

Cooperatives are typically developed to operate and maintain larger systems, especially isolated mini-hydroelectric or diesel-based systems. They require a willing attitude among most of the users and intensive organizational development and training. Their capitalization systems may not be flexible enough to reflect their members' willingness and capacity to contribute. But they provide a formal legal structure, have well-defined administrative and accounting procedures, tend to be self-regulating, and use democratic decisionmaking.

Cooperatives have not worked everywhere. But the international experience suggests that they can thrive where government policy explicitly carves out a niche for them (and does not allow incumbent utilities to discriminate against them) and people have the willingness to cooperate.

Rural energy corporations

Rural energy corporations are private companies formed to own and operate large isolated systems based on diesel or mini-hydroelectric plants. They range from a few partners to broad-based corporations. Compared with other rural energy organizations, they are more expensive to develop and require greater managerial sophistication and more centralized decisionmaking. But they have a formal legal structure, well-defined administrative and accounting procedures, and flexible capitalization mechanisms.

The Roatan Electric Company in Honduras, a broad-based corporation formed by 95 percent of the system's 5,000 users, has owned and operated a 6-megawatt diesel system since 1992. This small utility needed significant technical assistance and capital subsidies from the government to get started. But it is now sustainable—thanks largely to the wealth and managerial acumen of its customers and the skilled support of the many diesel operators and mechanics who work on Roatan's 300-boat fishing fleet.

The financing problem

While most off-grid systems have a long life, their initial capital cost is high and they can usually be financed only over short terms.

Countries are exploring several solutions to this dual financing problem. Two broad, and potentially complementary, approaches are possible. One is to subsidize service provision in some way (for more on subsidy design, see chapter 7). The second is to facilitate the extension of credit for new services through the finance market or through financing options offered by the service provider.

Subsidizing capital costs

Often governments subsidize the capital cost of systems, sometimes at 100 percent. A variant is to subsidize terms and rates for the financing of systems, which requires a continuous injection of funds. In another scheme, the off-grid utility concept, a private corporation sells the service provided by home photovoltaic systems for a monthly fee, which may be subsidized. Yet another option is to require a sizable down payment, but this can put the service out of reach for much of the rural population.

While rural households usually spend US$3–10 a month on alternative energy sources, some high-income rural households are willing to pay as much as US$50 a month. It is possible to "skim off" the market and serve these high-income users, even though they are few and far between. But solving their electrification problems may not do much for the problems of the majority.

In principle, subsidies to make service more accessible to users should be one-shot deals, not long-term support. Dependencies have a way of perpetuating themselves. The question is how to quantify and allocate subsidies.

The best and most common criterion for allocating subsidies is minimum subsidy per user. This criterion promotes both least-cost technology and maximum leverage. It is also best to have a ceiling on subsidies given by the project's economic net present value. While in theory a criterion of maximum net economic benefit has the most merit, in reality engineering cost estimation is much easier. And since the benefits of the first few kilowatt-hours—lights, a radio, a television—are similar for all technologies, least cost is an adequate criterion in small rural systems.

The mechanism for giving out subsidies through the market system must be founded on clear guidelines on who can benefit and how. It should be as open as possible so that anybody can apply for a subsidy—a utility wishing to serve some of its customers using photovoltaics, an individual user, a vendor, an association, a committee, or a developer. The process should be decentralized, open, and competitive.

In a competitive system the agents requesting the lowest subsidy per customer, including any organizational development and training, would be selected. In a system of pure competition the identification of customers, the selection of technology, and the process for setting prices would all be left to the market (the buyers and sellers), and the potential customers with greater willingness to pay and lower costs would get connected first. This system encourages innovation and participation. But it will inevitably have implications for regional development and poverty. These will need to be addressed in ways that do not undermine innovation and participation.

The subsidy mechanism should be open so that anyone can apply—a utility, a customer, a vendor, a community, or a developer.

Improving financing terms

Most subsidy schemes focus on the absolute level of capital costs involved in implementing either off- or on-grid systems and on their affordability to customers. But the term of available financing for these systems may also be a problem. Small hydroelectric plants should last for fifty years, photovoltaic panels for thirty to forty, and wind generation systems for at least thirty, but commercial financing is available for ten to fifteen years—at around 12 percent at best—to large photovoltaic developers. That contrasts sharply with the forty-year terms and 2 percent interest rates applied by the Rural Electrification Administration to develop rural grids in the United States.

Some thought has been given to creating guarantee funds for the residual value after a more conventional financing term has expired. By way of illustration, assume that most rural users can pay about US$5 a month. With 12 percent financing, the repayment period for a photovoltaic system costing US$500 would be a little more than twenty-six years, a term at which money is rarely available. After fifteen years, a more reasonable term, only about US$120 would be amortized and the rest would have to be refinanced. A guarantee fund would allow developers and vendors to get credit at normal terms and rates but with low amortization payments. At the end of the term there would still be a significant residual value to be refinanced. The fund would guarantee this residual value from the start, allowing financial institutions to secure the loans. Developers and vendors, who tend to analyze projects on a

cash flow basis, could pass the savings in capital costs along to the consumers.

A level playing field for financial and technical assistance—some options

Governments and donors must develop a mechanism for making subsidies and assistance broadly accessible. This could range from a small agency, much like a bank, that gives away money with the same care and responsibility that a commercial bank uses in making loans, to a more hands-on type of organization such as the U.S. Rural Electrification Administration. To work properly, such a mechanism needs:

- *A broad universe of projects to choose from.* With many diverse projects, a funding agency can select those projects with the best demand profile and organizational makeup and an adequate willingness and capacity to pay. As the market develops, projects to reach more marginal users will become increasingly feasible. To speed market development, each agency would disseminate information on its programs through all appropriate means (directly, through radio and television broadcasts, and by brochures, posters, and newspapers). While the agency could maintain a master database, it is the market—made up of individuals, communities, and companies—that would identify most projects.
- *A technology selection methodology.* The agency should identify, develop, and publicize tools for selecting technologies so that project developers can use them too and governments and donors can ensure that their resources are allocated optimally.[1] Even if the agency provides tools, the selection should be left to the market.
- *Appropriate system designs.* System designs must meet the customer's functional requirements—no more, no less. There must be functional requirements or design parameters for all major off-grid technologies so that subsidizers know that least cost is being attempted without sacrificing quality. Standards need to be appropriate and flexible (such standards may generate controversy, similar to the sensitivities associated with "appropriate technology"). And customers need to have some up-front choice, so that they understand the price-quality tradeoff in advance.
- *Technical support.* Training and organizational development must be part of the initial investment package. For home photovoltaic systems the bidding specifications must include training in how to use and maintain the systems. For a mini-hydro system they must include organizational development to be provided by a third party—an NGO or a community development group—under contract. Even if the organizational development program takes six months, its full cost must be included up front, as part of the initial investment package, and its financing provided for by the financial package, including any subsidy. The program should include training on how to operate, maintain, and replace systems and how to charge for services in a way that is affordable.
- *Competitive procurement of goods and services.* Free and open competition among equipment and service providers, under appropriate bidding terms and conditions, provides another opportunity for minimizing costs. Fair competition requires comparing apples with apples, so in addition to design and construction parameters, standard bidding documents for different technologies are often desirable. Fair competition should not mean a purchasing agency, merely facilitation. The Internet opens new possibilities for communities and developers to effect efficient purchases.
- *Reporting and follow-up.* Front-end subsidies create the least dependency and permit the least bureaucracy. But some believe that most problems surface down the line, requiring intensive follow-up to make sure that systems are being used and maintained appropriately. Can off-grid customers demand unlimited, reliable service at the flick of a switch in exchange for paying their bills on time? That depends on what market agents are willing and able to do at a certain site and point in time. Remote, poor, illiterate, and neglected households will continue to risk their savings on what they find in their limited markets. Subsidizers must take this into account when choosing follow-up strategies. At the very least, feedback reports will minimize future mistakes.

Conclusion

The key drivers of improved access to off-grid electricity service have all shifted the emphasis from a centralized toward a decentralized approach. Successful off-grid energy projects must understand and address, at the local level, the nature of the demand and its interaction with:

- The local energy source.
- The local operating organization.
- All possible project development actors, beginning with the communities and including community-level and other development programs.
- Other market agents, such as local vendors and electricians.
- Other energy suppliers.

Off-grid therefore means more than off-grid electricity supply. It means an expanded role for users, a diversity of organizational models, a greater reliance on local organizations, and a greater knowledge of both the energy supply in the broadest sense and the energy demand at the site. Planners, facilitators, and financiers all benefit from direct exposure to local conditions. The nature of the problem and the possible solutions are best defined at the site.

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Note

1. See Deloitte Touche Tohmatsu Emerging Markets and NRECA International 1998 for a discussion of technology selection methods based on net economic benefit.

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