NOVEMBER 2008

Operational Guidance for World Bank Group Staff

Designing Sustainable Off-Grid Rural Electrification Projects: Principles and Practices

THE WORLD BANK

The Energy and
Mining Sector Board

ACKNOWLEDGEMENTS

This Note was prepared by Ernesto Terrado, Anil Cabraal and Ishani Mukherjee. The Note has benefited immensely from the review and comments of both World Bank staff and external experts, and has been cleared by the Energy and Mining Sector Board. Special thanks go to the internal and external peer reviewers, Douglas F. Barnes, Jim Finucane, Christophe de Gouvello, Subodh Mathur, Kilian Reiche, and Dana Rysankova. Editorial support was provided by Norma Adams.

CONTACT INFORMATION

Questions and comments should be addressed to Anil Cabraal (acabraal@worldbank.org).

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The World Bank, Washington, DC

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ABBREVIATIONS AND ACRONYMS

ASTAE	Asia Sustainable and Alternative Energy Unit
CIF	Climate Investment Funds
CODE	Committee on Development Effectiveness
ERD	Decentralized Rural Electrification (Guinea)
ERTIC	Decentralized Infrastructure for Rural Transformation (Bolivia)
ESCO	Energy Service Company
ESD	Energy Services Delivery (Sri Lanka)
ESMAP	Energy Sector Management Assistance Program
GIS	Geographic Information System
GPOBA	Global Partnership for Output Based Aid
IDTR	Decentralized Infrastructure for Rural Transformation (Bolivia)
IEG	Independent Evaluation Group (formerly Operations Evaluation Department)
IESRM	Integrated Energy Services for Rural Mexico
IPP	Independent Power Producer
kW	kilowatt
kWh	kilowatt hour
LED	Light Emitting Diode
LV	Low Voltage
MSC	Medium Term Service Contract
MV	Medium Voltage
MW	megawatt
PERMER	Renewable Energy for Rural Markets Project (Argentina)
PERZA	Off-grid Rural Electrification Project (Nicaragua)
PIR	Rural Infrastructure Project (Honduras)
PMU	Project Management Unit
PPIAF	Public Private Infrastructure Advisory Facility
PV	Photovoltaic
REDP	Renewable Energy Development Project (China)
RERED	Renewable Energy for Rural Economic Development (Sri Lanka)
RERED	Rural Electrification and Renewable Energy Development (Bangladesh)
RET	Renewable Energy Technology
RPP	Rural Power Project (Philippines)
SBCS	Solar Battery Charging Station
SHS	Solar Home System
SSMP	Sustainable Solar Market Package
TEDAP	Tanzania Energy Development and Access Project
W	watt
WHS	Wind Home System
Wp	watt peak

FOREWORD

All countries—whether industrialized, middle income or low income—place a high priority on providing their citizens access to electricity. Despite this policy and the expenditure of billions of dollars, more than 1.5 billion people, mainly in Sub-Saharan Africa and South Asia, remain without access to electricity services today. To meet their lighting and other basic energy needs, many households continue to depend on expensive fossil fuel–based sources, such as kerosene, which are energy inefficient and polluting.

Fifteen years ago, grid extension, diesel-powered minigrids, and mini-hydropower generators were, for the most part, the only electrification options available to rural communities. With the commercial maturation of various small-scale, renewable energy–based technologies— from solar photovoltaic systems to small wind generators and micro hydropower—along with the evolution of innovative service delivery models, off-grid or stand-alone service provision has emerged as a viable alternative for increasing electricity access, especially in remote and dispersed communities. More recently, the dramatic rise in fuel prices has further increased the economic attractiveness of these technology options. Among the multilateral development banks, the World Bank is the leading financier of off-grid electrification, with projects across some 25 countries benefitting over 1 million households.

But the long-term sustainability of off-grid electrification depends on more than technology. It requires effective prioritization and planning to enable economic choices of technology, appropriate infrastructure to ensure that services are provided over the long run, and sustainable financing to make these capital-intensive technologies affordable. Drawing on some 15 years of experience in designing and implementing off-grid electrification projects in developing countries around the world, this Note offers World Bank staff and others interested in off-grid rural electrification projects guidance and insights into fundamental design principles for sustainability and sound practices for effective decision-making.

Jamal Saghir
Director, Energy, Transport and Water
Chairman, Energy and Mining Sector Board
Sustainable Development Vice Presidency

EXECUTIVE SUMMARY

Context	The evidence is clear that access to electricity has marked welfare improvements. There are 260 million rural households in the developing world without access to electricity. A significant portion of this population resides in small or dispersed communities or far from the national grid. Over the course of the past 12 years, the World Bank has supported a number of projects that provide electricity to such communities using approaches that are independent of a national or regional grid (off-grid). Experience from these projects offer guidance on designing sustainable off-grid electrification projects to serve dispersed and poorer communities using technology options that have attained commercial maturity over the past 15–20 years.
Purpose of the Guidance Note	Based on practical knowledge and international experience accumulated via past and ongoing World Bank operations, this Note aims to provide World Bank staff and others interested in off-grid electrification with useful guidelines for designing sustainable off-grid projects. Given the unique features of projects and country situations, the note does not seek to prescribe solutions for success. Rather, it offers basic design principles and sound practices for effective decision-making.
Organization of the Note	This Note is organized into three sections: (1) a Context and Background section, summarizing the rationale for off-grid electrification and its complementarity with grid-extension investment; (2) a discussion of Critical Factors in Project Design, analyzed by technology choice, social safeguards and environmental considerations, opportunities for productivity and institutional applications, affordability, appropriate business models, regulatory actions, and opportunities for international co-financing; and (3) Guidelines for Off-grid Project Designers.
Key Message	To maximize the chances of sustaining operation of off-grid electrification projects over the long term, their design must ensure that all key actors along the "value chain"—consumers, service and technology providers, financiers, and government—benefit.
Government Ownership	To increase the likelihood of sustainability, off-grid electrification projects must be consistent with a country's rural electrification plan for the region. Off-grid electrification must complement grid expansion. The government's recognition of the role of off-grid options is important; its support, including its subsidy commitment, and use of light-handed and simplified regulation, is essential. If the government is to have a significant implementation role, the implementing agency should appoint competent and dedicated project management staff. If access to financing is necessary and there is reluctance in lending, options such as partial guarantees, or access to longer term credit lines should be supported.
Technology Choices	Project design must not be technology driven. A cost-benefit analysis of alternatives (including grid extension) must be carried out to determine the least-cost solution. Technology choices must be based on practical considerations. The final choice must be left up to the service provider, who usually has other investment parameters to consider.
Delivery Mechanisms and Consumer Service	For off-grid projects that rely on private-sector participation, the simplest delivery mechanism or business model in line with local realities should be applied. Whatever business model is chosen, care must be taken to ensure that users have access to quality products and services at affordable prices and access to qualified repair service and spare parts over the long term.
Community Awareness	Maximizing the awareness and involvement of the beneficiary community early in the assessment phase is vital to the success of off-grid project implementation. Key activities include promotional programs, regular meetings with community leaders, and focus-group meetings.
Productive and Institutional Applications	Productive and institutional applications that improve lives and livelihood opportunities help those who cannot afford individual household connections or systems. From the perspective of private-sector providers and investors, such applications increase the economic attractiveness of the total business package for the community.
International Co-financing	Opportunities for international co-financing should be explored given the need for specialized demand studies, training of service providers and other vital preparatory activities, as well as the need to improve affordability of electricity services. Where subsidies are provided, obtain the government's upfront commitment to pick up the subsidy slack when external grant co-financing ends to ensure that implementation momentum is not lost.

CONTEXT AND BACKGROUND

Over the past two decades, World Bank investment projects and other programs have made impressive gains in improving electricity access in developing countries. Yet nearly 1.6 billion people across the developing world—more than 300 million households in both urban and rural areas—remain without electricity (IEA 2006). Of the nearly 260 million unserved rural households, many reside in isolated communities far from the national electricity network. These so-called "off-grid" communities are generally small and dispersed, consisting of low-income households—characteristics economically unattractive to potential private-sector energy providers or even government electrification programs that must prioritize the allocation of scarce resources.[1] Unserved consumers are also found in concentrated rural communities close to the grid and already electrified cities or towns. The electrification approaches and costs required to reach these three classes of unserved populations differ significantly, with off-grid consumers requiring more unconventional approaches.[2]

The push to privatize electricity generation and distribution in developing countries during the 1990s has, in some ways, exacerbated the problem of reaching those living in off-grid areas. Private distribution utilities, driven by bottom-line considerations, have concession contracts that limit their service obligation to households located a relatively short distance from the grid. Utilities have little incentive to connect customers located beyond this limit because unit connection costs are higher and customers, who are generally poorer, can only be charged tariffs that are below the marginal cost of service.

A recent report by the World Bank's Independent Evaluation Group (IEG) argued that Bank investments to improve access should assign priority to grid intensification—rather than off-grid electrification—as such projects have lower costs per connection and are relatively easier to implement (IEG 2007). In reality, government decisions for electrification investments are based on many country-specific factors, including equitable regional development, and are rarely either grid or off-grid decisions. Depending on a country's income level and stage of electricity infrastructure development, such decisions often involve trade-offs between financial viability and equity (World Bank CODE 2007).

Designing sound off-grid electrification projects is far from an exact science. The combination of high cost of service; poor customers; and newer, less familiar technology options often makes it a more complex task than preparing a conventional energy project. Nevertheless the evidence is clear: remote communities provided any type of decentralized electricity supply have marked improvements in welfare (Barnes 2007).

The benefits of rural grid electrification, which have been extensively studied and are well known, are similarly realized in off-grid situations, even though the amounts of power made available by decentralized systems are relatively smaller and the services provided more basic. For individual households, the main advantage is the shift from traditional to modern lighting systems, typically from kerosene lamps to the superior-quality electric lighting. Poorer community members benefit indirectly from the power provided to schools, health centers, water-supply systems, and communication facilities. Where community conditions are favorable, off-grid electrification stimulates the creation of microenterprises that increase overall economic benefits. For these reasons, some off-grid

[1] The forms of energy needed in off-grid areas are not limited to electricity. In the rural areas of developing countries, including already electrified areas, thermal energy from fuelwood for household cooking and use in small industries is by far the most predominant form of energy. Other World Bank initiatives, often related to forestry projects, are addressing the fuelwood supply-demand imbalance that many developing countries currently face.

[2] It is not possible to disaggregate the gross figures of unserved urban and rural populations precisely according to these three classes of unserved populations and thus estimate the total size of the off-grid market. Whether an unserved community belongs to the off-grid or grid-extension group is a function not only of distance but also of load density; thus, the size of individual communities must first be determined. In addition, unserved rural communities may be undercounted. In some countries, a community is counted as electrified once the low-voltage (LV) line has been built through it and a minimum number of connections made (for example, in the Philippines, 25 connections categorize a community as "electrified," regardless of the number of households that remain unconnected). Moreover, it has been argued that many unconnected consumers in areas already served by the grid could be classified as off-grid since the temporary solution to their "pre-electrification" status may be off-grid technologies, such as individual PV systems. A useful indicator is the national electrification rate: If this rate exceeds 80 percent, it is highly likely that only truly off-grid communities remain without electricity.

electrification projects have benefit-cost ratios that may exceed those of grid extension. In many World Bank–supported projects, the economic analysis of photovoltaic (PV) and other renewable energy–based, off-grid service mechanisms has consistently shown robust economic rates of return when gains in consumer surplus (resulting from access to higher-quality, lower-cost illumination with electricity compared to traditional fuels) are added to the avoided fuel costs.[3]

In 2002, a World Bank study estimated the socioeconomic benefits that a typical unserved rural household in the Philippines would gain from grid electrification (Barnes et al. 2002). The results, summarized in table 1, show that the benefits would be substantial relative to the low income level of the rural population. A similar study in Bangladesh reached the same conclusions (Barkat 2003).

From a broader planning viewpoint, the question is not choosing between grid extension and off-grid electrification but deciding how and when off-grid investments complement grid-extension projects. To this end, countries should adopt a rural-electrification planning framework that first compares the cost-effectiveness of the various investment options when delivering reasonable levels of service, and then factors in considerations of social equity and balanced regional development. The spatial-analysis approach being piloted in Kenya is one such example.[4] Other grid expansion decision-making approaches include multi-objective criteria (Indonesia), or revenue requirements per km of power line (Bangladesh). More development work is needed to improve such decision tools.

Table 1. Quantifying Electrification Benefits for a Typical Household in Rural Philippines

BENEFIT CATEGORY	BENEFIT VALUE (US$/MONTH)	CONSUMER TYPE
Less expensive and expanded use of lighting	36.75	Household
Less expensive and expanded use of radio and television	19.60	Household
Improved returns on education and wage income	37.07	Wage earner
Time savings for household chores	24.50	Household
Improved productivity of home business	34.00 (current business); 75.00 (new business)	Business

Source: Barnes et al. (2002).

In World Bank operations, off-grid electrification investments may be small components or subcomponents of larger rural energy or multisectoral projects. An example of the first type is the US$260-million Rural Electrification and Renewable Energy Development (RERED) Project in Bangladesh. Initiated in 1997, the RERED Project allocates about $230 million for rehabilitation, grid extension, and grid intensification in selected rural areas, while $30 million is earmarked for off-grid electrification. This project is supporting the installation of 8,000 SHSs monthly. The $47-million Rural Infrastructure Project (PIR) in Honduras, which invests in roads, water and sanitation, and rural electrification, exemplifies the second type. About 75 percent of the rural electrification component is for grid-extension investments, with 25 percent for off-grid systems. In Sri Lanka, several renewable-energy and energy-efficiency projects fall into this category (box 1).

In certain cases, projects may be dedicated entirely to off-grid electrification. Most of these are so-called "last-mile" projects. In Mexico, for example, where an electrification rate of 97 percent has been achieved, some 3.5 million people in the rural areas of southern states remain unserved because of distance from the grid, small size of communities, and general poverty. The recently initiated, US$98-million Integrated Energy Services for Rural Mexico (IESRM) Project is a

3 For PV, for example, the economic rate of return with consumer surplus ranges from 27 to 94 percent for projects in Bolivia, China, Indonesia, Philippines, and Sri Lanka.

4 Kenya is considering a geographic information system (GIS)-based, spatial-analysis planning approach to expand electricity access. For a projected load over 10–15 years, the analysis determines the least-cost grid rollout plan to meet the government's national- and rural-access targets. As part of the analysis, the least-cost off-grid rollout plan is configured for loads considered economically too small or remote to be connected to the grid. Because results can be viewed spatially, the approach may be effective in getting key stakeholders—from policy makers to communities—on board (Columbia Earth Institute 2007).

dedicated off-grid project that uses a variety of renewable energy technologies (RETs).

In the Pacific Islands, the US$9.5-million Sustainable Energy Financing Project for the countries of Papua New Guinea, Solomon Islands, Vanuatu, Fiji, and Marshall Islands focuses on off-grid electrification using mainly solar PV. Approved in 2007 and financed by the Global Environment Facility (GEF) and International Finance Corporation (IFC), this project draws on the results of an earlier, smaller activity that successfully provided solar home-lighting kits on commercial basis to 2,500 teachers as part of an effort to improve teacher retention in remote areas of Papua New Guinea. Under the project's financing mechanism, the GEF grant was used to extend the loan tenure to make monthly payments affordable, rather than using it upfront to reduce the purchase cost. Increased market volume and supply competition resulted in a 50-percent reduction in the cost of the kits.

Historically, World Bank staff has played a key role in advising and assisting clients in the early conceptualization and design phase of off-grid projects, often in relation to preparing broader rural-electrification or energy-sector lending. They have helped clients to conduct analyses, enabling them to make appropriate investment decisions and assess the technical, economic, financial, and institutional options for implementation. Today, off-grid electrification is an increasingly important area for World Bank energy-sector lending. A recent review of 120 World Bank electrification projects shows that, over the past decade, nearly half had off-grid components, compared to only 13 percent a decade earlier (IEG 2007).

Based on practical knowledge and international experience accumulated via past and ongoing World Bank operations, this Note aims to provide World Bank staff and others interested in off-grid electrification useful guidelines for designing sustainable off-grid rural electrification projects. Given the unique features of projects and country situations, the note does not seek to prescribe solutions for success. Rather, it offers basic design principles and best practices for effective decision-making.

BOX 1: Building on Success in Sri Lanka

Over the past decade, the Renewable Energy for Rural Economic Development (RERED) Project, launched in 2002, and its predecessor Energy Services Delivery (ESD) Project have helped thousands of poor rural households in Sri Lanka to switch from poor-quality kerosene lamps to more efficient electric lighting. The ESD Project, initiated in 1997, provided private-sector firms, nongovernmental organizations, and cooperatives small, output-based grants and medium- and long-term financing for SHSs and village micro hydropower in off-grid areas, as well as grid-connected mini-hydropower schemes. The US$45 million project resulted in electricity provision for over 22,000 off-grid households and private-sector investment in 30 MW of grid-connected, renewable-energy power plants. Building on this success, the RERED Project, with $75 million in IDA credits and $8 million in GEF grants, has supported private-sector investment in an additional 85 MW of grid-connected, renewable-energy electricity generation, more than 100,000 SHSs, and independent micro-hydropower grids. In 2007, an additional US$40 million in IDA financing was provided to support another 50,000 off-grid connections and 50 MW of renewable-energy, electricity-generation investments.

Implementing the private sector–led renewable energy program has created a vibrant local industry of suppliers, developers, financiers, consultants, and trainers. By June 2008, some 120,000 households were using SHSs, with 750 new installations occurring monthly. Nearly 6,000 households are obtaining electricity from micro-hydro minigrids that communities own, operate, and manage. One hundred MW of mini-hydro and biomass based–powered grid-connected plants are in operation and contributing 4 percent of electricity to the national grid. Another 25 MW are under construction.

Details are available at www.energyservices.lk.

CRITICAL FACTORS IN PROJECT DESIGN

Designers of off-grid electrification projects are responsible for a range of critical decisions that affect sustainability. These decisions include technology choice, ensuring affordability, social safeguards and environmental considerations, as well as taking advantage of opportunities to initiate and enhance productive activities and institutional applications. Project designers must also consider ways to use appropriate business models, determine necessary regulatory actions, and explore opportunities for international co-financing.

Comparing technology options

Once it is established that connecting an unserved community via grid extension is not justified, the next step is to determine which decentralized technology or mix of technologies is suitable.[5] Implicit in the overall process is the upfront collection of baseline data on energy consumption, income, and willingness to pay among the various sectors in the community and information on the availability of local energy resources. Where customers are few and dispersed and their main electricity use is domestic lighting, individual systems, usually SHSs, are used. Where water resources are available, pico-hydro systems of less than 5 kW have also been used for individual homes, small farms, or clustered households located near the river. For other World Bank projects, wind home systems (WHSs) are being piloted.[6]

Where most customers are concentrated enough to be economically interconnected into a microgrid or minigrid, a centrally located generating system—diesel generator, RET, or hybrid diesel-renewable—is the preferred solution. In World Bank off-grid projects, the most commonly used RET systems are run-of-the-river micro- or mini-hydropower plants and stand-alone, wind-power plants.[7] Less common are biomass-based power plants, such as small gasifier-engine systems or, for larger loads, direct combustion systems with steam turbines. Figure 1 illustrates the general decision-making steps in off-grid project design and the typical technology choices.

Diesel generators ranging from 5–10 kW portable systems to MW-capacity power plants have been the traditional solution to decentralized electrification needs. They can provide larger amounts of power at much lower investment cost per kilowatt than hydropower or wind-based alternatives. For off-grid applications, the two main drawbacks of diesel are 1) the high cost of fuel and its transport to the remote site and 2) the need for regular, skilled maintenance of equipment. The latter drawback also applies to certain RET systems, such as biomass gasifier engines. For these reasons, along with environmental considerations, World Bank–funded off-grid projects have generally avoided the use of diesel generators. Recent skyrocketing oil prices have dramatically increased recurring fuel costs and greatly diminished the low capital-cost advantage of the diesel option. Nevertheless, in many situations, diesel minigrids may still offer the most practical solution.[8] For example, the Decentralized Rural Electrification (ERD) Project in Guinea has 11 private concessions successfully operating isolated diesel minigrids, delivering 4–5 hours of daily service to their respective communities (Mostert 2008). In Cambodia, estimated 600–1,000 rural electricity enterprises are supplying some 60,000 rural households with electricity, typically using 100-kW diesel generators (Australian Business Council for Sustainable Energy 2005).

However, RETs that use wind, hydropower, and biomass face strict limitations imposed by site specificity and seasonality of resources. For example, micro- and mini-hydropower plants can only be built

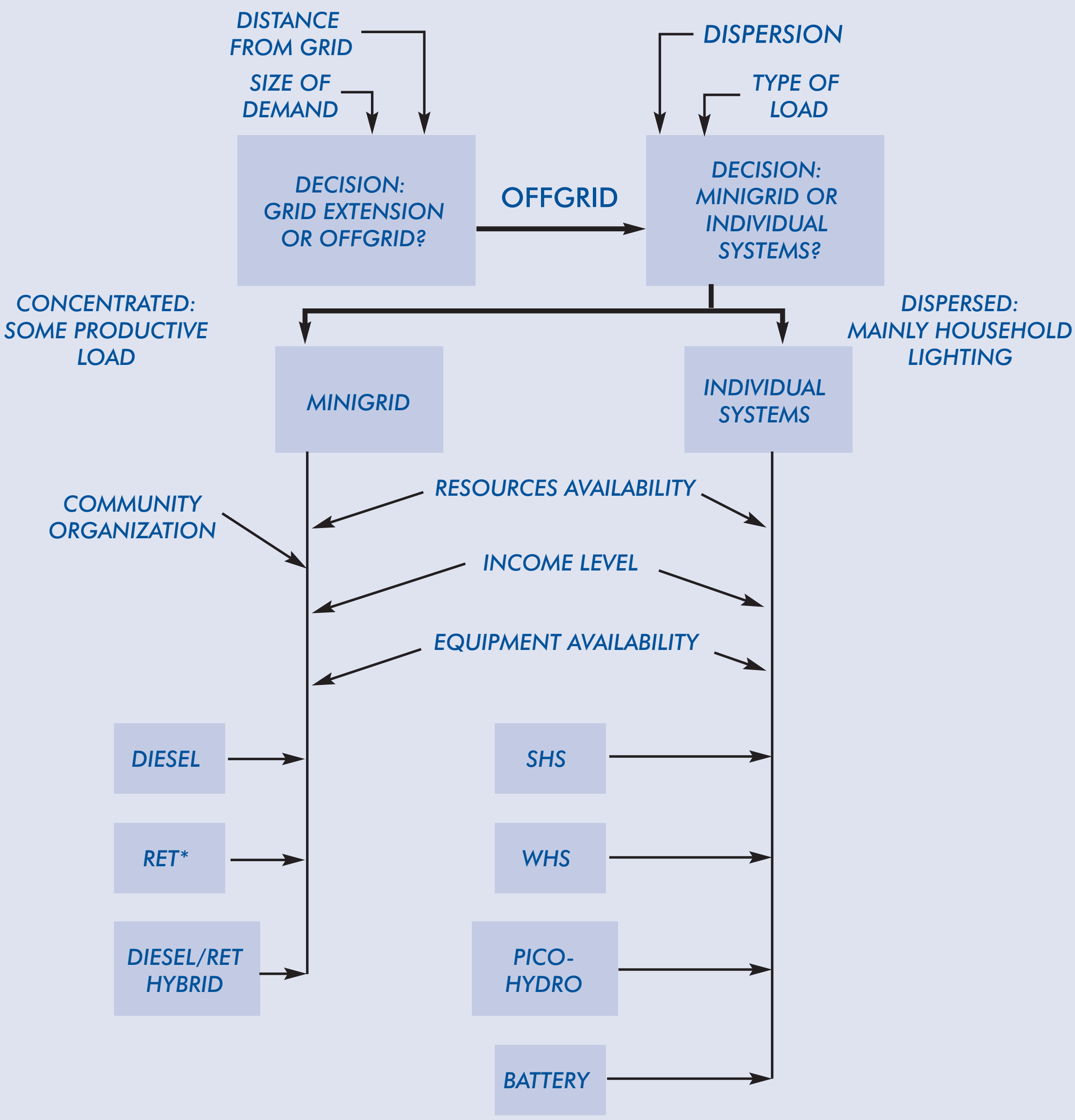
[5] In this context, "decentralized" refers to not being connected to the central electricity network. Some decentralized options for concentrated customers are centrally located (i.e., within the village) generation systems connected to isolated minigrids.

[6] A WHS is a commercially available, compact wind-turbine system that can deliver a monthly amount of energy comparable to a large SHS, depending on the average wind speed. An example is the Southwest Windpower Air X, which has a 1-m rotor diameter, a rated capacity of 400 W, and delivery of an estimated 38 kWh per month at a wind speed of 5.4 m per second. The system is priced at about US$600. World Bank projects in Argentina, Mexico, and Mongolia include WHS pilot components.

[7] Most countries define micro-hydro, mini-hydro, and small-hydro capacities as up to 100 kW, 100–1,000 kW, and 1–10 or 30 MW, respectively.

[8] For example, diesel minigrids may be preferred in locations that lack hydropower resources; have an uncertain wind regime, concentrated demand, and productive loads too large for PV; and where diesel supply is not too difficult to obtain and local persons can be trained as technicians for basic operation and maintenance.

FIGURE 1. TECHNOLOGY OPTIONS FOR OFF-GRID ELECTRIFICATION



**RET: WINDPOWER, SOLAR PV, HYDRO, BIOMASS GASIFIER, BIOMASS DIRECT COMBUSTION* at sites where hydropower resources meet minimum requirements for head and flow rates on a year-round basis. In certain cases, reaching such locations is extremely difficult for project staff and equipment providers. Wind-power systems require average wind speeds of at least 4 m per second for small turbines. To gain confidence in the continued availability of the resource, site monitoring of wind speeds must be conducted for at least a year prior to building a turbine. Biomass-based systems must be assured a constant supply of the appropriate type of biomass fuel over the project life. In several past World Bank–supported projects, meeting this condition has proven difficult. Seasonal and daily resource variability adds significantly to the cost since the off-grid generating source must be designed to meet the energy demand when resource availability is lowest. For example, a micro-hydropower plant large enough to supply demand during the dry season would have to dump the energy generated in the other months unless optional loads could be added at that time.

To circumvent the problem of intermittent resources, wind and even small hydro systems are sometimes hybridized with diesel generators. Such hybrid systems are used in cases where interruptions in electricity supply cannot be tolerated (e.g., cold storage of foodstuff in remote communities). PV systems have also been used in hybrid systems with diesel and wind but the significantly higher cost of PV may make such combinations uneconomic, except when the electricity is used to reduce expensive fuel consumption. Hybrids with diesel generators are possible only where diesel fuel can be reliably transported to the site and users can afford fuel costs that may escalate over time.

Several World Bank projects have piloted the use of centralized battery charging systems powered by solar PV, known as the solar battery charging station (SBCS). The SBCS can charge several batteries simultaneously with the use of modern automatic charge controllers. A typical station with a 2-kW capacity can serve the needs of about 50 households if the battery is used mainly for domestic lighting. The SBCS is suitable only in situations where all customers live near the station since the battery must be transported to and from the station for charging about once a week.[9] The SBCS was conceived as a technology for the poorest of the poor—those who could not afford to purchase SHSs. The idea was to allow such households to charge their batteries only when they could afford to, without any regular payment commitment. As explained in later discussions on delivery mechanisms, fundamental problems with the concept have been encountered in practice (box 2).

BOX 2: Solar Battery Charging Stations in Nicaragua: Solution for the Poorest?

In indigenous communities of Nicaragua's remote Atlantic Zone, seven solar battery charging stations (SBCSs), each with a 2-kW capacity, were installed in 2006. Each SBCS served some 50 households, and each family was provided a battery and lighting kit. The Nicaraguan government bore the capital cost of the stations and initial battery expenses. Beneficiary communities were trained to operate, financially manage, and maintain the stations. Each family paid a monthly fee of US$5 to cover weekly battery charging and contribute to a fund for buying replacement batteries.

The original concept was to allow families to charge their batteries only when they had available cash (much like the retail buying of cooking oil or firewood), but the concept proved unworkable in practice. To sustain the station business, each user family had to commit to regular monthly payments, which became a major stumbling block for this off-grid approach. Although community organizations managed SBCS operations well, the users—mainly poor subsistence farmers—eventually could not afford the monthly fees.

The Off-grid Rural Electrification Project (PERZA) has addressed this problem by working to raise farmers' incomes. For example, the Project has developed a customized microbusiness services program that assists in the bulk transport and marketing of crops and livestock and advises on agricultural matters. It has also arranged for non-cash payment for battery charging.

[9] With the advent of LED and its smaller power requirements, smaller and lighter rechargeable batteries can be used, thus reducing the difficulty of transport. The World Bank Lighting Africa initiative supports such applications.

Stand-alone batteries continue to be used in the unelectrified fringes of urban grids or rural minigrids of many countries. Households transport the batteries for charging to grid- or minigrid-connected charging stations run by private merchants as a side business. For diesel or hydro minigrids in off-grid electrification, adding battery charging stations makes economic sense as they have close to zero marginal cost when demand is lowest (e.g., daytime for a micro-hydro system).

The predominant technology used for individual households in off-grid projects is PV, mainly as SHSs. Typically, a SHS consists of a 10–100 Wp solar PV panel, a low-maintenance deep-cycle or modified automobile battery to store the solar energy collected in the daytime, a controller to regulate battery charging, cabling, and low-wattage DC lamps.[10] In World Bank projects, some 1.3 million PV systems for homes and community centers have been installed or are planned for installation, with a total capacity of more than 60 MW at a total investment cost of about US$680 million.

Over the past few years, advances in white Light Emitting Diode (LED) technology have made LED products commercially available for lighting applications, and reliability and quality have gradually improved. Assembled into mechanically or solar powered lights, such products might be considered when products cheaper than SHSs are needed to provide basic lighting services.[11]

The predominant role of PV systems in off-grid electrification is not the result of a technology bias by planners. PV is the only technology that can function virtually anywhere despite geographic variations in the resource (i.e., solar radiation intensity or number of days without sunshine). In most areas of developing countries, the solar resource is more than sufficient throughout much of the year to enable PV systems to function usefully. There is usually no need to conduct a solar radiation measurement program during the pre-investment phase. PV systems are modular and rugged; they require little maintenance (mainly periodic cleaning of the glass panel), although arrangements must be made to obtain spare parts and repair services.

Irrespective of technology choice, attention must be paid to ensuring that the products provided to consumers are reliable and deliver promised service levels. In past instances where quality was compromised to reduce investments costs, there were serious negative consequences in terms of consumer satisfaction. The resulting non-payments and reputational risks discredited the technologies and projects. Adequate attention must also be given to ensuring that consumers have convenient access to maintenance services and spare parts. In some past projects, quality systems were installed without providing for longer-term maintenance, which harmed the reputation of the project and technology.[12]

In practice, when an energy service company (ESCO) or private implementer is awarded an off-grid concession or market package, the desired service outcome for end users must be the only defined objective. In accordance with the principle of technology neutrality, the choice of technologies must be left to the service provider. If a project objective is to promote RETs, appropriate subsidies must be provided in order to level the playing field. But even in that case, the service provider, who often has other investment parameters to consider, must make the final choice.

Social safeguards and environmental considerations

Off-grid systems may use such products as lead-acid batteries and compact fluorescent lamps (CFLs), which must be recycled or disposed of safely. Off-grid electrification projects should coordinate with national recycling programs. In locations without such programs, arrangements must be made to educate users and require project implementers to recycle and ensure safe disposal of any hazardous waste. Mini- and micro-hydropower projects should adhere to national guidelines or regulations regarding watershed protection, land use, and land acquisition or adopt World Bank guidelines appropriate to the scale of intervention. Where minigrids are used, national electrical codes appropriate to the scale of the power

[10] In recent years, demand for portable solar lanterns, the smallest PV system (about 10 W), has surged, mainly because of affordability.
[11] The World Bank Lighting Africa initiative supports market development and quality improvement of such small, low-cost lighting products.
[12] The World Bank's Renewable Energy Toolkit (REToolKit) website provides information and examples of technical standards and references for qualified products used in current projects; details are available at www.worldbank.org/retoolkit.

system should be adopted. Examples of standards and specifications for solar PV, small wind, and micro-hydro minigrids can be found in the RETooIKit. The website of the Sri Lanka RERED Project also provides sound practices applicable to off-grid electrification.[13]

Productive and institutional applications

Many off-grid communities have economic activities that require energy or have a strong potential for initiating such activities but are constrained by a lack of modern energy supply. Economic activities are often related to agricultural production and processing, fishing or fish farming, livestock raising, water pumping, or small-cottage industries. Many require only small amounts of power (from 100 W to 3 kW), which could be provided by stand-alone RETs. Off-grid project designers must take advantage of any opportunity to initiate or enhance productive activities as they significantly increase the prospects for long-term project sustainability. The key ingredients are providing small private entrepreneurs or community organizations technical assistance and financing (table 2).

Table 2. Examples of Small-scale Productive Applications in Off-grid Areas

PRODUCTIVE APPLICATION	TYPICAL PEAK POWER REQUIRED	TECHNOLOGY
Cell-phone charging	5 W	PV
Electric fencing (grazing management)	20–100 W	PV
Water pumping (fish farming)	0.5–3 kW	PV, wind-electric
Grinding (corn and wheat) and milling (paddy)	0.5–3 kW	wind, PV/diesel hybrid, micro hydro
Refrigeration (dairy products, fish, meat)	0.5–10+ kW	wind, PV/diesel hybrid, micro hydro
Micro-irrigation	1–3 kW	PV, wind-electric, micro hydro
Ice making	2–10 kW	wind-electric, micro hydro

Source: Adapted from Weingart and Giovannuci (2002).

The cost of a micro-hydro system built to serve a small community's electricity needs may be sometimes justified only when productive loads—especially daytime loads—are large enough to supplement the nighttime household loads. If not, SHSs or other individual systems may be the least-cost alternative. The key is to ensure that the potential productive application is likely to happen once the micro-hydro plant is built. This means identifying the likely local participant for the microbusiness early on and assisting that individual in developing a business plan and identifying financing modalities. In many unsuccessful projects, the decision to build an expensive micro-hydro plant was based on consultant studies whose over-optimistic evaluation of potential productive applications proved impractical to implement. These types of projects fare much better where already-existing productive activities are powered by small diesel or gasoline engines; they not only indicate significant potential for utilization but also a high willingness to pay for electricity service.

Institutional or community applications are another important market segment for off-grid electrification. For example, the operations of schools, clinics, and community centers can be significantly enhanced by electric lighting, refrigeration, educational television, computers, communication and simple entertainment systems that require small amounts of power. In some World Bank projects, public- or donor-funded institutional applications have been used to offer a "critical mass" of business for PV market packages offered for bidding.[14] The winning bidder is given the right to access grant assistance to sell SHSs to households in the package area and a contract to install specified PV systems in selected institutions. An important feature of this model is the requirement to

[13] Details are available at www.energyservices.lk; "forms and specifications" links to various useful documents: environmental assessment TOR, environmental and social assessment and management framework, certificate of compliance (environmental and social assessment), post-completion environmental audits TOR, physical-asset verification form for village hydro projects (for environmental consultants), and guidelines on treatment of wooden poles.

[14] In the Philippines Rural Power Project, this type of initiative is known as the Sustainable Solar Market Package (SSMP) or Project ACCESS. Communities are clustered into viable business packages for PV installations consisting of households and public centers; PV installations and maintenance in public centers are paid for by the government or other private donors, while a partial grant makes household systems affordable. The contractor is obligated to provide services to a minimum percent of households in the area. SSMP contracts are competitively awarded. This approach is now being considered in Tanzania and Zambia.

provide long-term maintenance and services that meet specific service standards. The relatively large unit size of the institutional installation and its assured nature (as opposed to individual households, who may not opt to sign up) greatly increase the package's attractiveness to private-sector bidders. The paid-for requirement to service the institutional applications also creates the infrastructure to support retail sales in the same area.

A recent study has categorized these types of actions as systematic and pragmatic approaches (de Gouvello 2008). The systematic approach "analyzes the technologies used in the production processes of goods and services in a specific rural area. It identifies the bottlenecks, [determines] whether the use of electricity can contribute to diminishing or removing the limiting factors, evaluates the costs and gains, and provides guidelines to induce the proposed change in the processes. The pragmatic approach, on the other hand, follows an opportunistic tactic, taking advantage of pre-existing opportunities resulting from the ongoing or planned implementation of another project or program.[15] It is implemented when conditions are ripe for a quick-win project that would provide rapid revenue-enhancing gains, facilitated by access to electricity." The study argues that, to succeed, rural electrification programs should aim to generate new revenues and directly affect livelihoods.

Enhancing affordability

To increase affordability, off-grid project designers must consider the role of subsidies, consumer financing, low-cost technology options, and policies and business practices.

Role of subsidies

Like grid-based rural-electrification programs, off-grid programs may require subsidies, although operations are fully commercial in certain countries (e.g., solar PV in China and Kenya; several PV company operations in India; micro-wind in China and Mongolia; and pico-hydro in Laos and Vietnam). Compared to grid-connected customers, off-grid populations are generally poorer and more dispersed. At the same time, technologies for decentralized service, configured as individual units or minigrids, have higher investment costs but lower fuel and operating costs compared to diesel and other fuel-based supply systems. Even so, the resulting energy cost may exceed consumers' ability or willingness to pay. In such cases, subsidies can help off-grid consumers afford the high upfront cost of access.

Subsidies for off-grid populations are justified on social-equity grounds; that is, the need for remote or poor dwellers to achieve a level of parity with households in concentrated areas that benefit from subsidized grid-extension infrastructure costs and lifeline tariffs (table 3). There is also the expectation that the welfare gains from off-grid interventions are higher than the long-term costs (Barnes and Halpern 2000).

Market imperfections—potential investors' lack of information on specific opportunities, unavailability of long-term financing for the project type, and inability to collect tariffs that reflect the true cost of service—often prevent already economic off-grid projects or those

Table 3. Subsidy Levels for Grid-connected Customers

COUNTRY	GRID-CONNECTION SUBSIDY LEVEL (% OF CONSTRUCTION AND CONNECTION COSTS)[1]
Costa Rica	20–30
Chile	70–80
Honduras	85
China	85–90
Mexico	~95
Tunisia	100
Philippines[2]	100 (plus a portion of fuel and operating costs)

Source: Various World Bank reports.
[1] *Excludes subsidy for lifeline tariffs below the marginal cost of electricity supply.*
[2] *Diesel gensets.*

[15] For example, education ministry programs to improve school facilities or health ministry programs to upgrade rural health centers.

close to economic in lifecycle cost comparisons with conventional alternatives from being implemented. Appropriately designed subsidies for off-grid electrification enable the proposed physical interventions to occur sustainably by providing otherwise uninterested investors, equipment dealers, and service providers the needed financial incentives and support.

The key is to design subsidy mechanisms that are efficient (focused on the most economic projects), targeted (can reach poor consumers), and effective (are made part of implementation programs that work) (Barnes and Halpern 2000). For example, it is considered more effective to subsidize access (e.g., the upfront costs to consumers or business costs in the area) than operating costs. Subsidy instruments tested for off-grid electrification are varied and designed to match the type of delivery mechanisms chosen for specific technologies.[16] Table 4 illustrates the level of subsidies provided for SHSs in selected World Bank projects. The wide variation reflects system costs, willingness-to-pay levels, and government attitudes toward subsidy support.[17]

Various countries—for example, Bolivia, Laos, Nepal, Papua New Guinea, Philippines, Tanzania, and Zambia—provide subsidy support through rural electrification or rural energy funds that transparently cover the subsidy portion of electrification costs. Both grid and off-grid investments are eligible to receive support.

Role of Financing

Subsidies might be complemented or substituted by encouraging or supporting microfinance institutions, commercial or development banks, or even leasing companies to offer consumer and/or trade financing (box 3). Such arrangements can increase affordability by spreading first costs over several years. Since financing off-grid electricity products may be unfamiliar to the financing entity, credit enhancement, such as a partial risk guarantee, as in the Philippines, may help reduce the perceived risk to the lender. Some dealers have attempted to offer dealer financing; however, working capital constraints and lack of experience in credit-facility management have limited the success of such efforts.

Successful off-grid lending programs involve a strong partnership between the microfinance institution and an energy company. The effectiveness of that

Table 4. SHS Subsidy Levels in Selected World Bank Projects

COUNTRY	PROJECT	PV SYSTEM SIZE (WP)	APPROXIMATE SUBSIDY RANGE (% COST)
China	REDP	15–500	15–22
Bangladesh	RERED	20–70	12
Argentina	PERMER	50–100	up to 50
Tanzania	TEDAP	20–50	13–21
Sri Lanka*	RERED	10–60	10–25
Philippines	RPP	20–100	20–60
Mexico	IESRM	50–100	up to 90

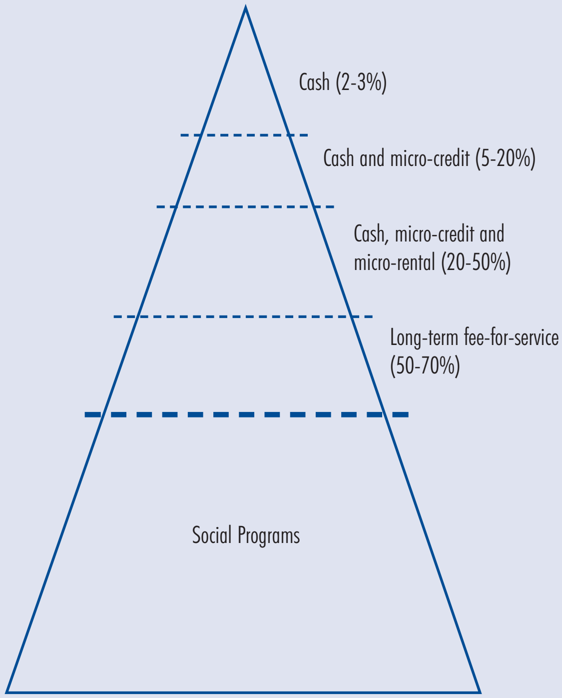
Source: Sources: Various World Bank reports.
**In Sri Lanka, the capital subsidy for micro-hydro minigrids is US$400 per kW or about 15–20 percent of investment cost.*

[16] To ensure that SHS subsidies target the poorest consumers, the product dissemination practice has been to skew the subsidy provided per watt of capacity toward the smaller systems.
[17] For World Bank projects in China and the Philippines, the most popular SHS has been the 20-Wp unit. The SHS subsidy in China is US$1.5–2 per Wp, compared to $12 per Wp in the Philippines, reflecting that country's higher product cost. The unsubsidized unit cost in China is $9 per Wp, compared to $20 per Wp in the Philippines.

BOX 3: The Rural Payment Affordability Pyramid

Even in poor off-grid areas, market segments often can support private sector–led microenterprises for electricity-service provision if the population base is large enough. Typically, 2–3 percent of residents can afford cash payment for the service. With microcredit, the customer base can reach up to 20–30 percent of residents. Microleasing may expand the market to 40–50 percent. Longer-term, fee-for-service arrangements could further reduce monthly obligations, thus reaching more poorer segments.

The base of the pyramid to the right represents the poorest of the poor, which may require fully subsidized social programs or small systems that offer limited service (e.g., a white LED lantern costing US$5–10). For PV projects including systems for schools, clinics, and other community establishments, some benefits are effectively extended to those who cannot afford to purchase their own systems.



Source: Adapted from Hansen (2006).

partnership depends on a clear understanding of the roles and responsibilities of each partner and their competency and capacity (Winiecki et al. 2008).

Role of Technology

One technical option to enhance affordability is to provide smaller, lower-power systems that offer a lower quantity of service (e.g., reduced hours of lighting), without compromising quality (Cabraal et al 1996). For example, a solar lantern costing US$50-75 can provide 3–4 hours of lighting daily. A 50-Wp SHS costing US$600 can operate four lights for 3–4 hours and power a radio or television for a few hours daily. Under the Renewable Energy Development Project (REDP) in China, where consumers had limited financial capability and lacked access to financing, most purchased low-cost 10- and 20-Wp SHSs (US$80-160) initially and larger 45-Wp systems (US$400) after their incomes increased. In Sub-Saharan Africa, the Lighting Africa initiative builds on the philosophy that small, modern lighting products can be marketed at prices similar to or lower than those rural households typically pay for kerosene by limiting services to lighting, taking advantage of LED technological advances and cost reductions, and tapping into Africa's existing distribution and retail infrastructure.

Attention to the quality of both products and services can also lead to reduced costs, as warranty repair and replacements can be expensive. Moreover, satisfied customers help expand businesses and hence reduce the relative share of overhead costs.

Role of Policies and Business Practices

Reducing the capital cost is another way to improve the affordability of capital-intensive off-grid technologies. In some countries, duty structures bias consumers against off-grid technologies, encouraging further consumption of kerosene and other less suitable alternatives that may be subsidized or exempt from the value added tax and other duties (IFC 2007). Such countries as Kenya and Tanzania have recognized the value of off-grid technologies, such as solar PV, and have exempted them from import duties. Since certain components of off-grid power systems have multiple uses (e.g., batteries), fiscal authorities are sometimes reluctant to grant duty exemptions, which can be abused. One option for governments to consider is to grant exemptions only for off-grid equipment that has met prescribed quality standards. Larger-volume procurements or orders that are predictably and regularly placed with suppliers may receive discounts. Building long-term relationships with suppliers may be beneficial, as some will offer supplier credits and help reduce working capital requirements. Project procurement rules should permit taking advantage of such incentives. A larger-scale operation will also reduce the share of costs attributed to management, sales, and overhead.

Business models for off-grid service: central role of the private sector

World Bank–supported off-grid electrification projects principally aim to improve electricity access for populations in remote areas that are unlikely to be reached by grid extension within a reasonable time frame. Intertwined with this goal are the objectives of having players other than governments implement the work, mobilizing additional human and financial resources, and reducing pressure on already overextended utilities. Alternative players could include private-sector companies or individuals, nongovernmental organizations, or community-based organizations (for examples, see Gunaratna 2002). The key is to develop a system of incentives sufficiently attractive for these players to do business in off-grid areas.

For isolated minigrids, system location and scale, income profile of potential customers, and available subsidies dictate whether the enterprise can attract private investors/operators. If so, the business model involves calculating a tariff roughly commensurate with consumers' ability and willingness to pay and, if necessary, providing sufficient capital subsidy to assure the investor/operator a reasonable profit. Additional support involving technical assistance, site surveys, feasibility studies, and capacity-building may be provided to the investor during the project development phase. Since establishment of minigrids are premised on the development of productive loads, the community or relevant individuals may also require related technical and financial assistance.

Micro-grid systems in isolated areas are unlikely to attract private-sector interest. A prevalent business model in such cases involves organizing the community to become the owner and operator, providing maintenance, tariff collection, and management services. Understandably, such a community-based model requires substantial technical assistance in design and feasibility studies, training, and social organization, as the Nicaragua case illustrates (box 2).

As part of its rural electrification program, the government may offer funding and invite proposals from private-sector or nongovernmental organizations. Alternatively, the government may establish a rural energy fund and offer to support such investments on a first-come, first-served basis. In either case, it is sound practice for the government to subsidize a portion of the capital cost, while the community or private sector covers the balance investment cost and full cost of operation and maintenance. In setting up community-owned and -managed, micro-hydro grids in Sri Lanka, the communities borrow from banks to supplement a subsidy of about 15–20 percent of the capital costs (box 1).

A third approach is one where a public utility or government-contracted ESCO operates a small, isolated microgrid. In this case, tariffs are regulated (e.g., set at a level equivalent to the lifeline tariff of rural grid customers). The utility or ESCO operator is provided a subsidy from a cross-subsidy fund or other public source of capital and perhaps a portion of operation-and-maintenance costs. This model is now being applied in China to operate more than 700 centralized, PV microgrids, each with a 10–150 kW capacity. The Philippines has used such an approach for many years to fund its isolated diesel operations.

For individual systems, most World Bank experience has centered on commercial dissemination of SHSs, starting in 1996 with the first PV rural-electrification lending operation in Indonesia. Today, several projects feature PV as a component of a broader energy or infrastructure operation or dedicated off-grid electrification effort (Energy and Mining Sector Board 2007). The largest such effort to date is located in remote areas of northwestern China, where, at project end in June 2008, sales of more than 400,000 systems had been achieved, benefiting 2.5 million people.

The business models for commercial PV dissemination may be classified as 1) dealer (direct sales or open market) and 2) fee for service (ESCO). In the dealer model, the consumer purchases the system either with cash or financing. Beyond warranty service, the consumer assumes responsibility for all operational and replacement costs. In World Bank projects, the dealer model often features microfinance assistance, which addresses the issue of high upfront costs.[18] In the fee-for-service model, the consumer is provided electricity service, the level of which depends on system capacity. The company, which retains ownership of the equipment, is responsible for maintenance and providing replacement parts over the life of the service contract.

An early fee-for-service example is the concession model applied in the Renewable Energy for Rural Markets Projects (PERMER), initiated in Argentina in 1999. Franchise rights to rural-service territories were granted to concessionaires that required the lowest subsidy to provide households and public centers service in the concession areas. Although concessionaires could choose from a wide range of off-grid technologies, PV was determined the most cost effective for many remote areas with dispersed customers. This model was considered suitable, given Argentina's long experience with concessions for concentrated electricity markets. Thus, the requisite regulatory framework and procedures for dispersed markets could be easily added to the existing system.

The Senegal Rural Electrification Project, initiated in 2003, used a similar concession model with exclusivity rights. But in this case, the total subsidy was predetermined. The winning bidder for a concession area was the firm that offered to provide the most connections in the first three years; the firm was also required to make a minimum number of connections beyond 20 km from the grid (de Gouvello and Kumar 2007). One non-Bank project widely considered a successful example of the concession system is the Morocco project, with a target of 180,000 SHSs, initiated by the National Electricity Office in 2002. Today, the main concessionaire, Total EDF *Maroc Solaire* (TEMASOL)—a joint subsidiary of EDF (*Electricité de France*) and Total—operates in 24 provinces with 53,000 customers (TEMASOL 2008).

The model used in the World Bank–supported Decentralized Infrastructure for Rural Transformation (IDTR) Program in Bolivia can be viewed as a hybrid of the above-mentioned models. Known as the Medium Term Service Contract (MSC), this model adds mandatory local-market development and 2–5 years of operation-and-maintenance services to the dealer-model requirements for participating companies. The model can also be considered a revision of the traditional ESCO concession scheme, whereby the exclusivity term is reduced to only 2–5 years and opened to a broader menu of ownership options (box 4).

Variations on the above-described models include the leasing model—pioneered by Soluz in non-Bank projects in Honduras and the Dominican Republic—which falls between the two categories. A SHS is

[18] An exception is the China project, which lacked rural-credit facilities; in this case, consumers were used to paying cash, and no microfinancing was introduced. The issue of high upfront costs was addressed by driving down costs in various ways, particularly with low retail margins, using "plug-and-play" systems that required no installation and focusing on smaller, more affordable units. Initially, consumers bought small systems (10–20 Wp); subsequently, as their incomes rose, they bought larger ones (40–100 Wp).

provided to the consumer via a direct lease or lease-to-own agreement. The sustainable solar market package (SSMP) used in the Philippines combines a tendered contract for institutional installations with incentives and the non-exclusive opportunity to sell SHSs to households in the area (box 5).

The dealer model usually allows accredited dealers to sell anywhere in the country. But in certain World Bank–supported projects (e.g., PIR in Honduras and PERZA in Nicaragua), subsidies are provided only for sales in designated priority areas, although microfinance assistance is less restricted geographically.

BOX 4: Medium Term Service Contract: Output-Based Aid Model in Bolivia

In 2003, the Decentralized Infrastructure for Rural Transformation (IDTR) Program was initiated in Bolivia. This 10-year, US$60-million effort aims at increasing rural access to electricity and information and communication technologies via decentralized public-private partnerships that benefit from performance-based subsidies or output based aid (OBA). For PV market development, the Program adopted the Medium Term Service Contract (MSC), an approach between traditional concessions (of longer duration) and the dominant SHS dealer or credit-line model (competition in the market without exclusive areas). The MSC model is thought to fit Bolivia's "last-mile" market conditions: increasingly difficult-to-reach rural markets in extremely remote areas.

In 2005, 14 service contracts, ranging from 350 to 2,200 future SHS users in size, were successfully bid out in a one-stage, multi-lot tender. To minimize subsidies the government had to pay private providers, each area was awarded to the qualified bidder promising to service the largest number of users at a given total subsidy per area, with well-defined performance indicators. Price caps were set to prevent monopoly pricing, while minimum user requirements per area were fixed to prevent excessive unit subsidies.

Out of 11 pre-qualified consortia, two bidders were awarded the SHS tender, and subsidy contracts for all 14 service areas were signed. An intensive road show in 2005 was essential in attracting enough bidders. After an initial delay, implementation started in July 2006, and more than 1,000 SHSs were installed by the end of that year. Both providers maintained their original targets despite changes in Bolivia's investment climate and regional shortages of SHS equipment supply.

Source: Reiche, Rysankova, and Goldmark (2007).

BOX 5: Sustainable Solar Market Package in the Philippines

The Sustainable Solar Market Package (SSMP) is a contracting mechanism that provides for the supply and installation of PV systems, along with a maintenance-and-repair contract (e.g., 5 years with an option to extend) in a defined rural area. Applications in schools, clinics, and other community facilities are bundled with requirements and incentives for commercial sale to households, businesses, and other nongovernmental customers. Funding for the public and community-services facilities is provided by the government or other donors, while a grant is used to help household consumers defray the cost of SHSs. They either obtain a loan from a partner microfinance institution or pay cash for the balance of the SHS payment. By bundling applications in a defined area, the SSMP approach addresses key affordability and sustainability issues of past PV projects: standardization, reduced transaction costs, larger business volume, and reduced risk. In the Philippines, 7 SSMP contracts benefiting 76 villages are currently being implemented, with preparation of more packages under way to benefit 400 villages.

Source: Philippines Department of Energy (2007).

There are no clear-cut rules for determining which SHS-dissemination model is appropriate for a given project in a particular country. The dealer, ESCO, and MSC models have their comparative advantages and disadvantages. The dealer model is easier to launch, requiring only the accreditation of several participating dealers and establishment of a microfinance support system, as needed. Competition in all phases of implementation could, in theory, lead more quickly to cost reductions and better service for consumers. Conversely, because the model is fully market driven, the pace of coverage is hard to predict or control. The ESCO model has the potential to achieve faster coverage and obtain lower equipment costs due to volume transactions. At the same time, it requires more complex regulatory procedures that are often hard to establish in many countries. Lack of competition once territory is acquired may suppress innovation and lead to lower-quality service, and cost savings from volume procurements may not be passed on to consumers. The MSC hybrid model combines most of the above-described advantages of the dealer and ESCO models, while avoiding some of their limitations (e.g., via emphasis on post-sales maintenance requirements and reduced exclusivity term). Compared to the dealer model, however, it takes more time to prepare (since it is usually tendered), and improvised adjustments are more difficult to make. Like the concession model, he MSC hybrid model requires that a competent, transparent, and effective regulatory system be in place to assure service quality.

Country conditions are important determinants of model choice. In countries where the potential SHS market is economically attractive in terms of scale and geography and where there are enough qualified prospective competing companies, the dealer model (with attention paid to after-sales service) may be appropriate. Where universal access is the national goal or the market is unattractive (e.g., small and highly dispersed communities, consisting of uniformly poor households located in difficult-to-access terrain), the ESCO or MSC hybrid model may offer a better approach. In many countries, SHS market features are mixed, which may call for a combination of models.

Regulating off-grid service

The government is responsible for ensuring off-grid customers do not pay excessive tariffs or suffer from poor-quality service, regardless of the service-provision mechanism used. At the same time, the regulatory requirements developed for traditional grid extension are inappropriate for off-grid markets. Where possible, reporting and service-quality standards in smaller off-grid systems in rural areas should be set lower than for the main power grid so that costs can be reduced, tariffs lowered, and electricity services made more affordable for rural users (Reiche, Tenenbaum, and Torres 2006).

For SHS service, the "natural" regulator is the government agency that provides subsidies for system purchase and installation. Regulatory actions involve accreditation of participating companies, settings and enforcing standards (preferably adopting internationally accepted standards)[19], verification of installations, and random monitoring of system performance—actions that World Bank–supported projects usually require of counterpart government agencies. For isolated minigrids or microgrids, simplified methods for graduated regulation have been proposed, depending on system capacity and size of the population served. A key principle is to avoid over-regulation. For example, it is generally agreed that service-quality standards should be lower for operators of systems below 300 kW. Operators in this lowest-size category would have no obligation other than to register once and provide an annual update of basic information. Operators would be allowed to set tariffs corresponding to the cost of providing service in the specific areas.

International co-financing assistance

Designers of off-grid electrification projects must be aware of opportunities provided by international grant-financing facilities. Since its creation in 1993, the Global Environment Facility (GEF) has been the traditional co-financier of World Bank off-grid electrification projects through grants provided for

[19] The REToolkit offers guidance on procedures for setting and enforcing standards, including use of products with proven experience in other World Bank projects, or products with quality certification and labeling such as PVGAP (www.pvgap.org) or Golden Sun (www.cgc.org.cn/eng/news_show.asp?id=4).

RETs that are ready for practical deployment but face market barriers. Grant assistance is well-appreciated by recipient governments as it not only reduces the subsidy burden but provides a level of comfort to planners still unsure of the effectiveness of renewable-energy alternatives for electrification.

More recently, the Global Partnership for Output Based Aid (GPOBA) has become an important source of grant assistance for off-grid electrification. GPOBA's goal is to apply output-based approaches to support the delivery of basic services to the poor, not only for electricity but also for water, sanitation, telecommunications, transportation, health, and education. The most common grant applications are one-off, transitional, and ongoing subsidies. One-off subsidies involve capital subsidies aimed at increasing access to services. Transitional subsidies help to fill the gap between what the user is able or willing to pay and the cost-recovery level of the tariff. Ongoing subsidies are required where there is a perpetual gap between affordability and cost recovery, including consumption costs. A recent example is the Bolivia Decentralized Electricity for Universal Access Project, which obtained US$5.2 million in grants from GPOBA to finance, on an output basis, the installation of 7,000 PV systems for rural households, schools, clinics, and micro and small enterprises. In addition, the GPOBA provides technical-assistance grants for project design and evaluation and disseminates lessons learned.

Off-grid electrification projects inherently require more preparation resources than conventional grid-based projects. Often one must first determine the willingness-to-pay profiles of communities via surveys, conduct resource measurements (e.g., site-specific wind regimes), organize and train potential service providers and community leaders, and promote business models to prospective companies. A key challenge for off-grid project designers is potential service providers' lack of capacity, making training in such basic skills as business and financial management imperative. Such studies and activities may be eligible for grant financing provided by the Energy Sector Management Assistance Program (ESMAP). The World Bank–managed Asia Sustainable and Alternative Energy Unit (ASTAE) and Public Private Infrastructure Advisory Facility (PPIAF) could also provide grant financing for technical-assistance activities related to off-grid electrification.

The Clean Development Mechanism (CDM) of the Kyoto Protocol may offer opportunities for enhancing the financing of off-grid projects through carbon credits for renewable-energy systems or even conventional systems whose practices mitigate emissions (e.g., switching to CFLs). In principle, all technologies that avoid or significantly reduce fossil fuel–based generation are eligible for CDM credits.[20] In practice, however, the volume of avoided carbon emissions must be sufficiently high to offset the transaction costs of CDM processing, possibly making many smaller off-grid projects ineligible. It must also be noted that carbon credits are not provided upfront to help with investment costs, but become effective a year after the installation has become operational. Recently, Bangladesh signed contracts for the purchase of emission reductions to be achieved by its large solar PV dissemination program for remote off-grid areas. The program targets about one million SHSs installed by 2015, totaling more than 50 MW and avoidance of 84,000 tons of CO_2 per year at full implementation.

The Climate Investment Funds (CIF), approved by the World Bank Board of Executive Directors in July 2008, is a potential funding source for off-grid and renewable-energy projects in developing countries. The CIF is expected to comprise of two trust funds—the Clean Technology Fund and Strategic Climate Fund. The Clean Technology Fund will provide financial resources for projects and programs in developing countries that contribute to the demonstration, and lead to large-scale deployment of low-carbon technologies (World Bank 2008a). The Strategic Climate Fund, broader and more flexible in scope, will serve as an overarching fund for various programs to test innovative approaches to climate change (World Bank 2008b). The CIF is

[20] Details are available at http://carbonfinance.org.

currently under development and donor resources are being mobilized.

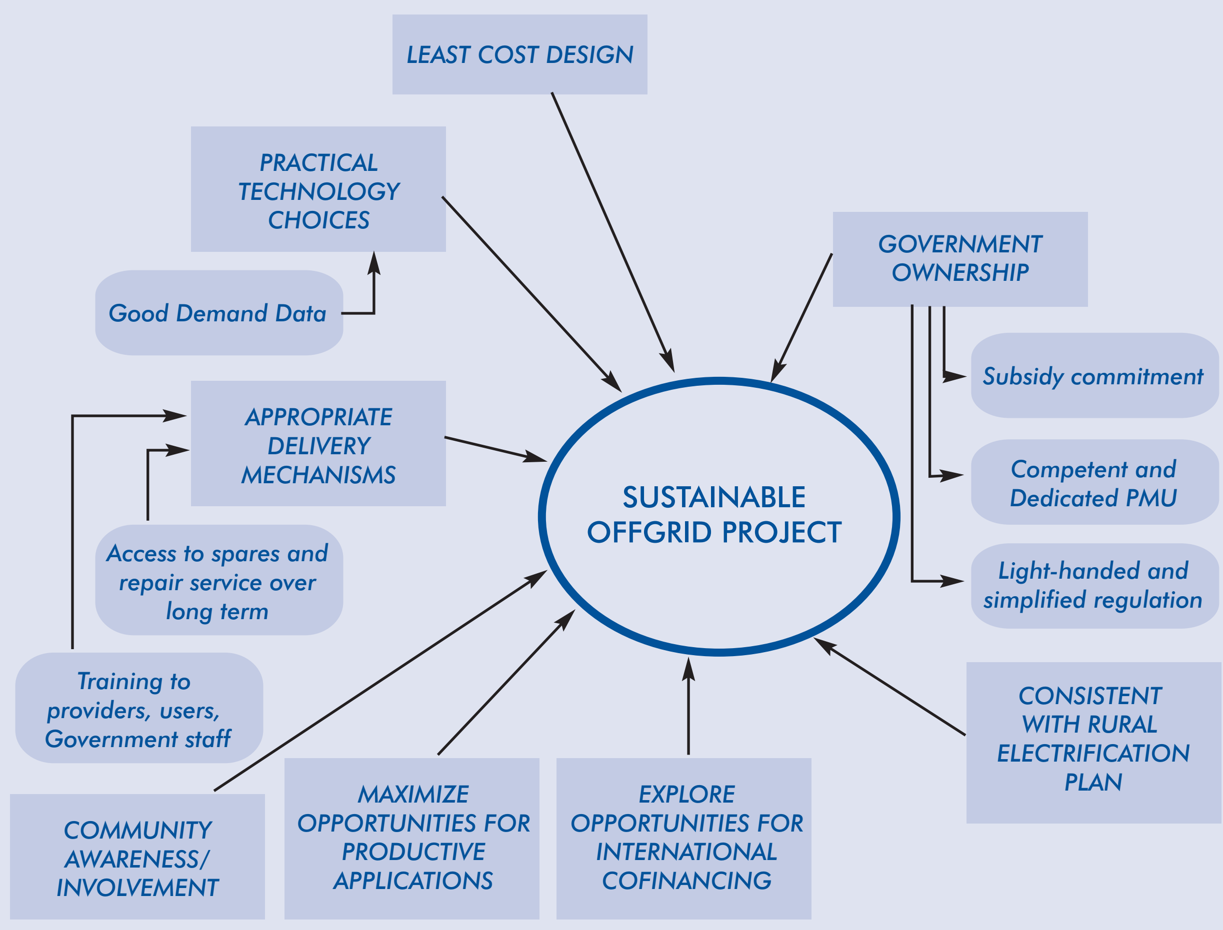
GUIDELINES FOR OFF-GRID PROJECT DESIGNERS

To maximize the chances of sustaining operation of an off-grid electrification project over the long term, fundamental project design principles must be observed, as follows (figure 2):

- **The conception and implementation of the off-grid project must be consistent with the overall rural electrification plan for the region.** The project should not be influenced by such ad-hoc factors as one-time availability of donated renewable-energy equipment or pressure exerted by local politicians, which can be unsustainable.

- **Project design must not be technology driven.** A cost-benefit analysis of alternatives must be

FIGURE 2. ELEMENTS OF A SUSTAINABLE OFF-GRID ELECTRIFICATION PROJECT



carried out to determine the least-cost solution. Choice of technologies must be based on practical considerations (e.g., technology maturity, year-round adequacy of resources, ease of operation and maintenance, continuity of [biomass] feedstock supply, and access to spare parts and service). Data on energy consumption and income and willingness to pay across various sectors in the community should be collected upfront and factored into the technology-selection process.[21] When implementation is awarded to an ESCO or private implementer, the desired service outcome for end users must be the only defined objective; choice of technologies must be left up to the service provider, who usually has other investment parameters to consider.

- **Early in the assessment phase, efforts must be made to maximize community awareness, involvement, and support, which are vital to project success.** Starting at project inception, target communities can be reached via promotional programs, regular meetings with community leaders, and organization of focus-group meetings.

- **Both the government and implementing agency must take full ownership of the project.** Because off-grid electrification is generally more difficult to implement than traditional grid-extension projects, persistent and concerted effort is required by the government and World Bank teams.

- **One must obtain the government's upfront commitment to pick up the subsidy slack when external grant co-financing ends to ensure that implementation momentum is not lost.** Grant co-financing by international donors for the cost of hardware is often provided on a declining basis and ceases at project closure. For continuity, consideration should be given to making off-grid projects eligible for accessing rural energy funds.[22]

- **Competence of the local Project Management Unit (PMU) is critical to project success.** One must obtain implementing agency commitment for appointment of competent PMU staff and that such staff will devote their time to the project.

- **For off-grid projects that rely on private-sector participation,** the simplest delivery mechanism or business model (or mix thereof) commensurate with local realities should be applied. The design must reflect the capabilities of the service providers, adequately address their risks, provide technical assistance, ensure appropriate technical standards and performance requirements, establish access to adequate financing, and ensure the timely disbursement of funds.

- **The government must put in place light-handed regulatory measures that simplify operations for private-sector participants and limit the cost of doing business, while adequately protecting consumers.** Whatever business model is chosen, care must be taken to ensure that users have access to quality equipment and products and qualified repair service and spare parts over the long term. The REToolKit provides examples of technical standards and references to specific products that have been tested and used in various World Bank projects over the past decade.

- **Appropriate training should be provided to participants of off-grid projects at various levels, including government staff, potential service providers, and consumers.** Government staff requires training at a broader level, from basic technical aspects to electrification planning. Small private companies, who may already have technical expertise, need instruction in business and financial management, marketing, and project procedures. Community-based providers may need basic training in equipment operation and business. Consumers require guidance in system selection and operation and choosing the service level best suited to their needs. Sufficient project resources should be allocated for this purpose.

[21] World Bank staff preparing off-grid projects may find it useful to consult the REToolKit website, which offers a wide range of materials and tools that are useful in making technology choices and developing general project-design strategies.

[22] For example, the Philippines created a Missionary Electrification Development Fund and formulated a subsidy rationalization policy specifying the terms for providing off-grid systems assistance from the fund (Philippines Department of Energy 2004).

- **One should maximize opportunities for productive and institutional applications that complement the provision of household service.** Institutional and community applications that improve livelihood opportunities and generate new revenue (e.g., information and communication technologies) help those who cannot afford individual connections or systems. Such considerations are especially important for micro-hydro and other RETs for isolated grids, which have high capital costs and may not be economically justified on the basis of providing lighting and other household uses alone. From a private-sector provider or investor perspective, such applications increase the economic attractiveness of the total business package for the community.

- **Opportunities for international co-financing should be explored.** Such funding sources might include the World Bank's Global Environment Facility (GEF) or Global Partnership for Output Based Aid (GPOBA), the Clean Development Mechanism (CDM) of the Kyoto Protocol, bilateral donors, or a country's sectoral ministries (e.g., health or education). Given the need for specialized demand studies, training of service providers, and other vital preparatory activities, staff should take advantage of opportunities to obtain grants for such purposes.

REFERENCES[23]

Australian Business Council for Sustainable Energy. 2005. *Renewable Energy in Asia: The Cambodia Report—An Overview of the Energy Systems, Renewable Energy Options, Initiatives, Actors and Opportunities in Cambodia*. Carlton, Victoria: Australian Business Council for Sustainable Energy. Available at www.bcse.org.au.

Barnes, Douglas F. (ed.). 2007. *The Challenge of Rural Electrification: Strategies for Developing Countries*. Washington, DC: Resources for the Future.

Barnes, Douglas F., and Jonathan Halpern. 2000. *Subsidies and Sustainable Rural Energy Services: Can We Create Incentives Without Distorting Markets?* ESMAP Technical Paper No. 010. World Bank, Washington, DC. Available at esmap.org/filez/pubs/subsidysustainabdec2000.pdf.

Barnes, Douglas F., Aleta C. Domdom, Virginia G. Abiad, and Henry Peskin. 2002. *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits*. ESMAP Report No. 255/02. World Bank, Washington, DC. Available at esmap.org/filez/pubs/ruralelecphillip.pdf.

Barkat, Abdul. 2003. "Rural Electrification and Poverty Reduction: Case of Bangladesh." Paper presented at Sustainable Rural Electrification in Developing Countries: Is It Possible?, international conference of NRECA International, Arlington, Virginia, March 6–7.

Cabraal, Anil, Malcolm Cosgrove-Davies, and Loretta Schaeffer. 1996. *Best Practices for Photovoltaic Household Electrification Programs*. Asia Technical Department Series, No. WTP 324. Washington, DC: World Bank. Available at www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187283&siteName=WDS&entityID=000009265_3961214152456.

Columbia Earth Institute. 2007. "National Electrification Coverage Planning: Investment Costing Estimation Model: Kenya." Draft final report of Energy Group submitted to the World Bank, Washington DC.

de Gouvello, C. 2008. *Maximizing the Productive Uses of Electricity to Increase the Impact of Rural Electrification Programs*. ESMAP Formal Report No. 332/08. World Bank, Washington, DC. Available at esmap.org/filez/pubs/618200840844_technical_april08.pdf.

de Gouvello, C., and G. Kumar. 2007. "OBA in Senegal: Designing Technology-neutral Concessions for Rural Electrification." *OBA Approaches,* Note No. 13. Available at www.gpoba.org.

Energy and Mining Sector Board. 2007. *Catalyzing Private Investment for a Low Carbon Economy: World Bank Group Progress on Renewable Energy and Energy Efficiency in Fiscal 2007*. Washington, DC: World Bank.

Gunaratna, Lalith. 2002. *Rural Energy Services Best Practices,* United States Agency for International Development, South Asia Regional Initiative for Energy, New Delhi, India. Available at www.sari-energy.org/ProjectReports/RESBestPracticesExecSum.pdf

Hansen, R. 2006. "Nicaragua PERZA: OBA Subsidies for PV Systems." Final Report to the World Bank, Washington, DC.

IEA (International Energy Agency). 2006. *World Energy Outlook 2006*. Paris: Organisation for Economic Co-operation and Development. Available at www.worldenergyoutlook.org/2006.asp.

IEG (Independent Evaluation Group). 2007. *Welfare Impact of Rural Electrification: A Reassessment of Costs and Benefits*. Washington, DC: World Bank. Available at go.worldbank.org/ZE4B692E10.

[23] All weblinks confirmed as active on August 14, 2008.

IFC (International Finance Corporation). 2007. *Selling Solar: Lessons from More than a Decade of IFC's Experience*. Washington, DC: International Finance Corporation. Available at www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/p_SellingSolar/$FILE/SellingSolar.pdf.

Mostert, W. 2008. *Review of Experiences with Rural Electrification Agencies: Lessons for Africa*. Draft report, March. World Bank, Washington, DC.

Philippines Department of Energy. 2004. *Streamlining and Rationalizing the Grant of Subsidies in the Electrification of Missionary Areas Using Solar Photovoltaic Systems*. Manila: Philippines Department of Energy. Available at www.doe.gov.ph/popup/DC%202004-05-005.pdf.

———. 2007. *Accelerating Community Electricity Services Using Solar (Project ACCESS) Using the Sustainable Solar Market Package Concept*. Manila: Philippines Department of Energy. Available at www.rpp.com.ph/documents/SSMP2%20Brief_Dec07.pdf.

Reiche, K., B. Tenenbaum, and C. Torres. 2006. *Electrification and Regulation: Principles and a Model Law*. Energy and Mining Sector Board Discussion Paper No. 18. World Bank, Washington, DC. Available at http://siteresources.worldbank.org/EXTENERGY/Resources/336805-1156971270190/EnergyElecRegulationFinal.pdf.

Reiche, K., D. Rysankova, and S. Goldmark. 2007. "Output-Based Aid in Bolivia: Balanced Tender Design for Sustainable Energy Access in Difficult Markets." *GPOBA Approaches*, Note No. 12. Available at www.gpoba.org.

REN21. 2008. *Renewables 2007 Global Status Report*. Paris and Washington, DC: REN21 Secretariat and Worldwatch Institute. Available at www.ren21.net.

TEMASOL (Total EDF Maroc Solaire). 2008. *Concession de l'energie solaire*. Available at www.edf.fr/html/global_compact/pdf/access_maroc_va.pdf.

Weingart, J., and D. Giovannuci. 2002. *A Guide to Developing Agricultural Markets and Agro-enterprises*. ESMAP Report. World Bank, Washington, DC. Available at go.worldbank.org/1DBLU3WAQ0.

Winiecki, Jacob, Kristen Cortiglia, Ellen Morris, and Sonali Chowdhary. 2008. *Sparking Strong Partnerships: Field Tips from Microfinance Institutions and Energy Companies on Partnering To Expand Access to Energy Services*. Washington, DC: Small Enterprise Education and Promotion (SEEP) Network and Sustainable Energy Solutions. Available at www.seepnetwork.org and www.sustainable-solutions.com.

World Bank. 2008a. "Clean Technology Fund." June. World Bank, Washington, DC. Available at siteresources.worldbank.org/INTCC/Resources/Clean_Technology_Fund_paper_June 9_final.pdf.

———. 2008b. "Strategic Climate Fund." June. World Bank, Washington, DC. Available at siteresources.worldbank.org/INTCC/Resources/Strategic_Climate_Fund_final.pdf#Strategic_Climate_Fund.

World Bank Committee on Development Effectiveness (CODE). 2007. *Management Comments on the Independent Evaluation Group (IEG) Report "Welfare Impact of Rural Electrification: A Reassessment of Costs and Benefits."* World Bank, Washington, DC. Available at siteresources.worldbank.org/EXTRURELECT/Resources/code.pdf.

Websites of interest:

Asia Sustainable and Alternative Energy:
www.worldbank.org/astae

Carbon Finance Unit:
carbonfinance.org

China General Certification Center
www.cgc.org.cn/eng

Energy Sector Management Assistance Program:
www.esmap.org

IDTR (Bolivia)
www.idtr.gov.bo

Global Environment Facility:
www.thegef.org

Global Partnership for Output Based Aid:
www.gpoba.org

Public Private Infrastructure Advisory Facility:
www.ppiaf.org

PVGAP
www.pvgap.org

Renewable Energy Toolkit:
www.worldbank.org/retoolkit

RERED (Sri Lanka)
www.energyservices.lk

RERED (Bangladesh)
www.idcol.org/energyProject.php

RPP (Philippines)
www.rpp.com.ph

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The World Bank
1818 H Street N.W.
Washington, D.C. 20433
USA